CONCEPTS OF SCIENCE

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R. G. Cull W. A. Drake

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Preface

This book is the first of a series of four. It is intended to provide an introductory science course for students in year seven in Australian schools.

The authors have attempted to produce a *tidy* book — one that will be easy for students to use. For this reason, each chapter contains the following sections:

- A complete unit of information that students will be able to use to find answers to questions raised in their science course.
- A section describing in detail experiments suitable as investigations to be carried out in the time normally allocated for science lessons. This section includes questions related to particular experiments.
- A summary of the factual content of the chapter.
- A spelling list.
- Further suggested experiments presented in far less detail than the first group.
- Questions extending from the subject matter of the chapter as a whole — mainly of the essay type.
- A short objective test covering the subject matter of each chapter and testing how well it has been understood.

By using this format, the authors hope they have produced a book that will be useful both at home and in the classroom.

R. G. C.
W. A. D.

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R. G. C.
W. A. D.

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Introduction

This chapter may be the beginning of your science course. If it is, you may be asking yourself: "What is science about? Why do we study it at school?". The word "science" comes from the Latin word *scientia*, meaning knowledge — knowledge about ourselves and the world around us.

Most people are curious about things around them — especially about unusual things. For example, many people have been interested in the albatross. The albatross usually nests on a rocky ledge near the sea. After nesting and rearing its offspring, it migrates north to warmer areas. Every second spring it returns to the same place and builds a new nest with the same mate. To do this it has to fly thousands of kilometres over the ocean. How does it find its way? Does anybody know? How could we try to find answers to these questions?

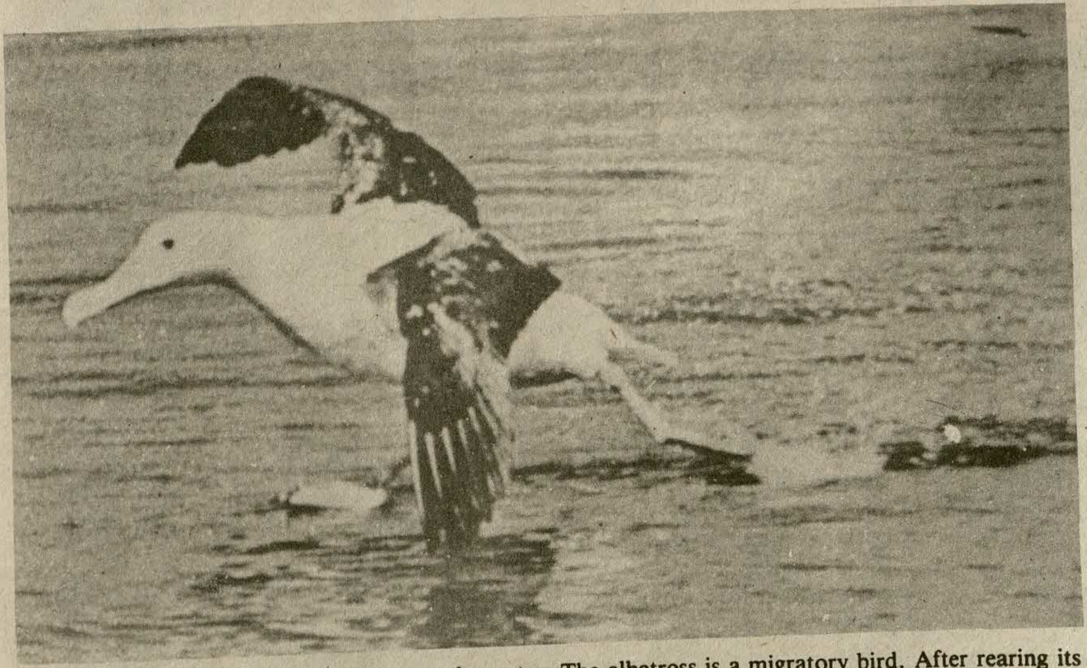


Figure 1.1: An albatross taking off from the water. The albatross is a migratory bird. After rearing its chick it travels many thousands of kilometres, but it always returns to the same place for the next mating season. How do these birds find their way back to the same spot over such long distances? (Photo courtesy *Courier-Mail*)

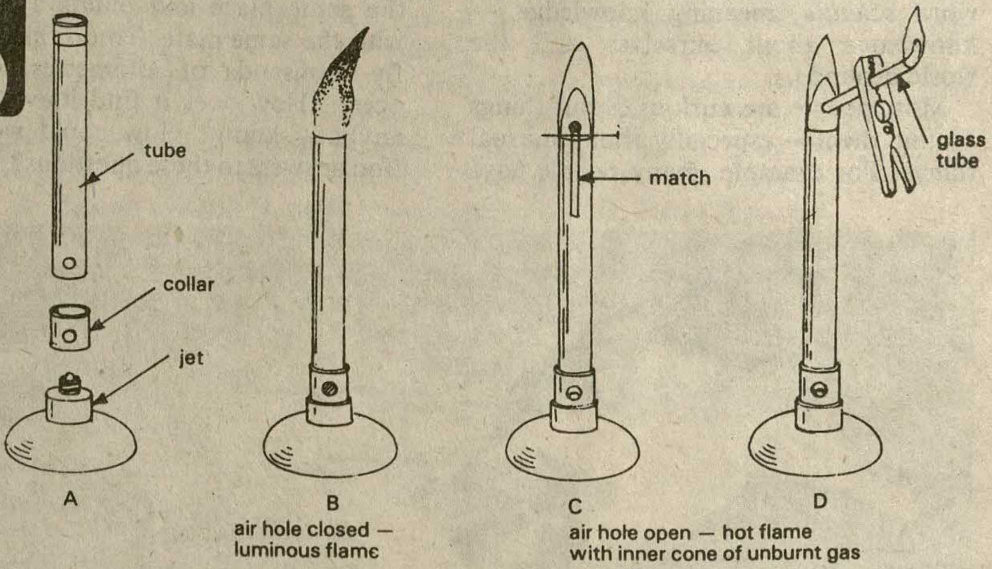
Another interesting thing is the way bees are able to communicate with each other. They can tell each other where to go to get good supplies of nectar from flowers. Do you know how they do it? (There would be a book in your library that contains the answer.)

The flight of the albatross and the communication of bees are two of many problems that scientists have sought to solve. You too, no doubt, have asked yourself many questions, such as: "How does this work?" and "Why does this animal behave in this way?". Your science course will help you to understand the answers to many questions; it will also show you how scientists themselves find the answers to the questions they ask.

As this is probably your first day in a science laboratory, it is best that you first learn something about the apparatus you will be using. Then you will learn some simple techniques.

EXPERIMENT 1.1

Learning to use the Bunsen burner and finding the hottest part of its flame



B
air hole closed — luminous flame

C D
air hole open — hot flame with inner cone of unburnt gas

Figure 1.2: Learning about the Bunsen burner.

Each group will need:

- Bunsen burner
- porcelain dish
- piece of glass tubing about 8 cm long
- piece of screwed-up paper
- safety match
- pin
- piece of nichrome wire
- tongs
- piece of cardboard about 15 cm square

What to do

- Turn the collar of the Bunsen burner and examine the jet. Gas comes out of the jet and mixes with air drawn in through the opening in the collar.

Figure 1.3: Scientists working under water searching for a particular seaweed.

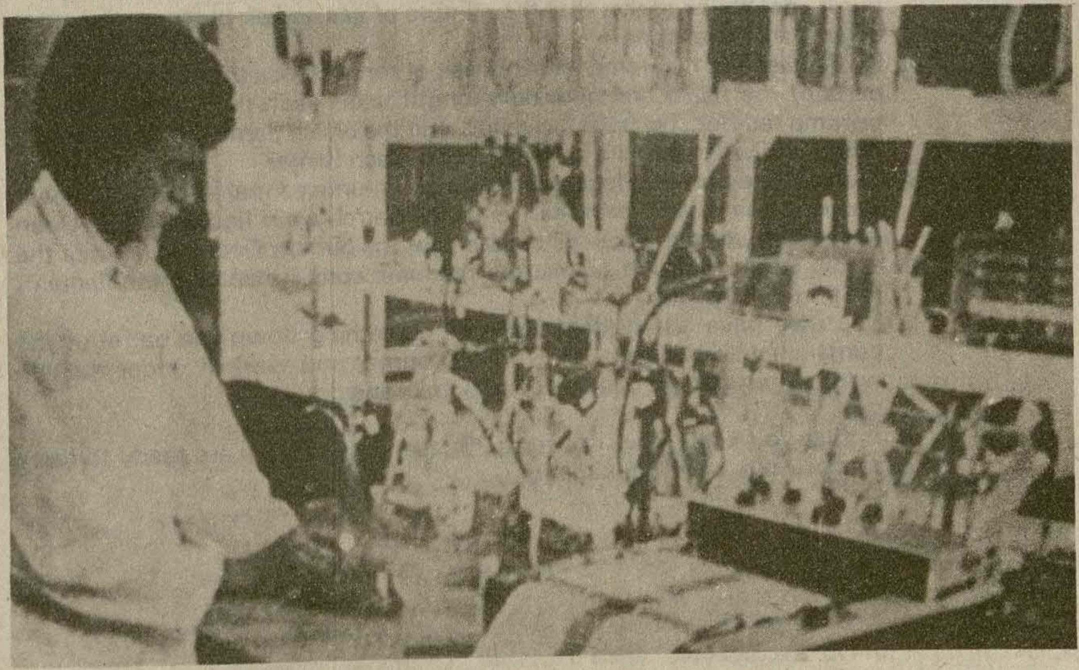


Figure 1.4: A scientist working in a laboratory analysing the chemicals that have been extracted from the seaweed referred to in figure 1.3.

- Turn the collar so that the air hole is closed. Turn the gas tap half on. Light the burner by holding a lighted taper at the side of the barrel near the top. This is the safety flame: it can be easily seen. The burner should be left like this if it is alight but not being used.
- Turn the gas full on. Notice the luminous yellow flame. Hold a cold porcelain dish in the flame. What is the substance deposited on the surface of the dish? The yellow flame is a dirty flame and is not normally used for heating.
- With the gas full on, gradually open the air hole. The flame becomes less visible and the burner may become noisy. Notice the blue inner cone in the flame.
- Leaving the gas burning full on, light a piece of screwed-up paper. Extinguish the flame on the paper by smothering it between sheets of cardboard. Hold the smoking paper near the air hole of the burner. Notice how the smoke is drawn through the hole by the jet of gas.
- Leaving the air hole fully open, gradually turn down the gas supply. You will probably hear a ''pop'' and find the gas burning at the jet at the bottom of the barrel. The burner has ''struck back''. It should not be left burning in this way because the barrel will become hot. When the burner strikes back, turn off the gas and then relight the burner with the air hole closed. Open the air hole slowly until the yellow flame just disappears.
- Hold a short piece of glass tubing in the flame at an angle, as in figure 1.2(D). One end of the tubing should be in the inner cone of the flame. At the same time, apply another flame at the other end of the tubing. What can you conclude about the inner cone? It seems that the inner cone is unburnt gas. It also seems that the mixture of gas and air burns on the outer edge of the inner cone.
- Hold a piece of nichrome wire in a pair of tongs. Place the wire in different parts of the flame and note how long it takes each time for the wire to become red-hot. Try both the yellow and the bluish flames. Which flame is hotter and where are the hottest parts of each flame?
- Turn off the burner. Place a pin through an unused match near the head. Suspend the match from the top of the barrel, as in figure 1.2(C). Open the air hole, turn the gas full on and light the burner. Does the head of the match catch alight? It seems that the inner cone is cool and the flame of the burner is hollow.
- You may have an accident and spill something down the barrel of the burner. If this happens, turn off the burner and wash it under running water. Then stand it upside down to drain and dry.

Now that you know how to use the Bunsen burner, you are ready to carry out a more extensive experiment.

EXPERIMENT

1.2

Separating a mixture of sand and salt

Each group will need:

- paddle-pop stick
- sand
- table salt
- 2 cm test tube
- filter paper
- filter funnel
- Bunsen burner
- filter stand
- glass rod
- 200 mL beaker
- small clock glass wide enough to rest on top of beaker
- gauze
- tripod

What to do

- First make your mixture. Use the end of a paddle-pop stick to measure equal quantities of sand and salt onto a piece of paper. Make only enough mixture to cover a cent piece. What do you think would be the best way to separate the ingredients of this mixture? The method we are going to use depends on the fact that salt dissolves in water and sand does not.
- Add the mixture to a 2 cm test tube and pour in about 3 cm of water. Shake with a sideways motion to dissolve the salt.
- Fold a piece of filter paper first into halves, then into quarters, then into eighths, and so on until you can't fold the paper any more. When opened out the paper will look like figure 1.5.

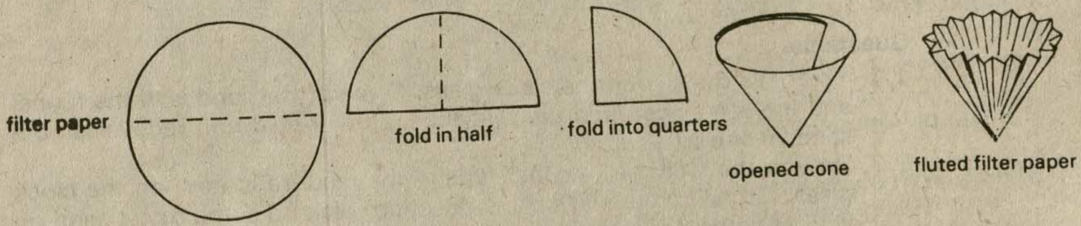


Figure 1.5: Two ways of folding a filter paper. The fluted paper gives faster filtering because there is space for the filtrate to run down between the paper and the glass of the filter funnel.

- Place the fluted filter paper in the funnel and the funnel in the stand, as shown in figure 1.6 (next page). Place the clock glass under the funnel.
- Give the test tube a quick shake and pour the contents quickly into the filter paper. Some wet sand may be left in the test tube but don't worry about it at this stage.
- Half fill the beaker with water and place it on the gauze on the tripod, as shown in figure 1.7 (next page). Make sure the gauze is flat. Place the clock glass on the beaker. Light the burner and place it under the gauze.
- After a time the water in the beaker will boil and the heat from the steam will cause the water in the clock glass to evaporate. Eventually you will be left with a deposit of dry salt in the clock glass. You have separated the salt from the sand.

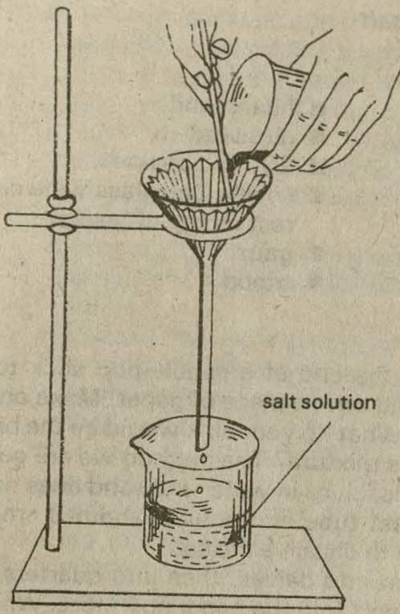


Figure 1.6: Separation of salt and sand by filtration. The sand is kept back by the filter paper and the salt solution passes through.

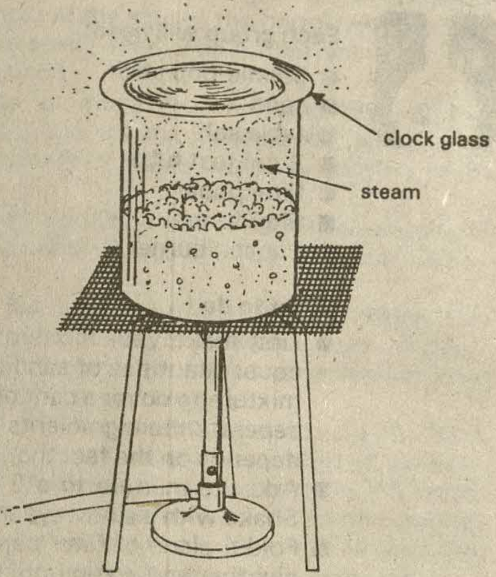


Figure 1.7: Evaporating a solution. The steam from the boiling water causes rapid evaporation of the solution in the clock glass.

Questions

1.1 You have the salt on the clock glass. Some of the sand is in the funnel and the remainder is in the test tube. How would you recover all the sand, in one little heap?

1.2 Do you think all the salt that was in the mixture is now on the clock glass? To help you answer this question, pick up some moist sand on your fingertip and taste it.

1.3 Would it be possible to get a complete separation of these two ingredients? How?

When the apparatus you have been using is cool, dismantle it ready for storage. Place the used filter paper in the bin. Make sure no rubbish is left in the sink. A blocked sink makes it difficult to carry out experiments.

Safety in the laboratory

In doing your first experiments, most of you will have seen that, without care, you could have had accidents. You probably have more chance of having an accident in the science room than in other rooms of your school. The most common injuries from such accidents are:

- damage to the eyes and skin from spilt chemicals
- cuts from broken glassware
- burns from hot equipment or hot chemicals

- scalds from boiling water.

Dangers that might cause accidents are called hazards. Crossing a busy street is a hazard. What are some of the things you can do to reduce this hazard?

Think back over your first two experiments. What were the hazards? Suppose we tabulate some of them.

Hazard	Possible accidents
Using a Bunsen burner	■ Someone could pick up a burner that had struck back. ■ Someone could lean against a lighted burner that was standing close to the edge of the bench. ■ Someone with loose long hair leaning over a burner could have their hair catch fire.
Shaking the test tube with the mixture in it	■ Some drops of mixture could splash out into someone's eyes. ■ The test tube could be broken by being dropped or knocked against something.
Beaker on a gauze on a tripod	■ The beaker could have slid or been knocked off the gauze. ■ The beaker could have cracked while the water was boiling.

Questions

1.4 Can you think of any other hazards in these experiments?

1.5 Would an overcrowded laboratory be a hazard? Why? What about a person running in the laboratory?

1.6 Suppose some boiling water spilt onto someone's hand. How would you treat the scald? Do you know where the first aid kit is?

1.7 Does your science room have a fire blanket? How would you use it if some spilt methylated spirits caught alight?

1.8 Is there a separate waste bin for broken glass? Who could have a nasty accident if broken glass were put into an ordinary garbage bin?

Spelling list

accident
barrel
Bunsen burner
collar
disappear
evaporate
extinguish
funnel
gauze
hazard
ingredient
kilometre
laboratory
luminous
methylated spirits
porcelain
science
scientist
separate
suspend
tripod

More questions

1.9 Draw a diagram of the apparatus used in experiment 1.2. Label each part.

1.10 Which would be the easier mixture to separate into its ingredients — a mixture of sugar and salt or one of sand and salt? Why?

1.11 What are some of the hazards in (a) your kitchen, (b) your bathroom? How can you reduce the risk of accidents from these hazards? Tabulate your answers.

1.12 A home gardener decides to grow some tomato plants, starting from seeds. He buys a packet of seeds and, at the same time, asks the shopkeeper for a packet of fertilizer "to make the seeds germinate quickly". The shopkeeper tells him he is wasting fertilizer if he puts it in the seed box. "Put fertilizer in the garden bed once the plants are established, but don't use it in the seed box — you could do more harm than good," he says.

The home gardener doesn't believe the shopkeeper. He decides to find out for himself whether fertilizer helps seeds to germinate (start growing). He doesn't know whether to use method 1 or method 2.

Method 1. Fill a seed box with soil. Mix in fertilizer at the recommended rate — a handful to the square metre. Plant the seeds and see how long they take to start growing.
Method 2. Use two seed boxes, one with fertilizer and one without fertilizer. Plant half the seeds in one box and the other half in the second box. Compare the results.

Which would be the more scientific approach? Assuming the home gardener uses method 2, would you agree that he should do all of the following things?

- Use the same sort of soil in each box.
- Have the same depth of soil in each box.
- Place the boxes in the same position.
- Give the same amount of water to each.

1.13 What do you know about the dolphin?

- Is it a fish or a mammal (an animal that feeds its young at the breast)?
- How does it breathe — through gills or by using some other method?
- How do dolphins "talk" to one another?
- Have you seen a dolphin in an aquarium leap through a hoop above the water? How are dolphins trained to do this?

1.14 Did you know that the large ears of the elephant help to keep it cool? Heat leaves the body from the large number of blood vessels in the ears. Are there any other animals with very large ears that help cool them down? Are there any in Australia?

1.15 Scientists and engineers in a number of countries are working to develop an electric automobile. The batteries are the main problem in an electric car. A petrol-powered car has one battery for starting the motor; an electric car would need a large number of batteries.

Would you agree that the research workers have to develop a battery that is:

- lighter in weight than today's battery
- smaller
- cheaper
- able to be recharged more quickly
- able to hold a bigger electric charge?

What are the two main advantages of an electric automobile over a petrol-driven vehicle?

2

Your environment

Your environment is everything around you. The word "environment" has a wider meaning than you might at first think. For example, we speak of a man working in a noisy environment, or a desert animal living in a dry environment. Even changes — those that happen again and again — are part of the environment. For example, floods are part of the environment of the people living on the banks of the River Ganges, in India.

We hear people talking about "an unpleasant environment". Could an environment be pleasant for one person and unpleasant for another? Do you think you, yourself, are part of your environment?

Exploring your environment

Your laboratory is part of your environment. As you look around, you see the teacher, other students, desks, chairs, taps, blackboard, walls and windows. Looking through the windows you see the environment outside the classroom.

Scientists are interested in sorting things into groups, that is, classifying things. For example, when they discover a new animal they try to place it in one of the groups they have worked out for animals. Even though you had not seen a new animal, you would know a lot about it if you were told it was a spider, say, or a bird.

Suppose, for fun, we decide to classify objects in the classroom. How shall we start? First let us make a list of all the things we can see. Has anybody listed fifty things?

Secondly, how shall we group these things?

- Large or small?
- Living or non-living?
- Metallic or non-metallic?
- Natural or manufactured?

Can you think of any other possibilities?

Choose a system of classification; rule two columns in your notebook and write down each item on your list in its correct column. Do you agree that a good system should have about half the things in one column and the other half in the other column?

Are there any things in the room that you cannot see? There are bound to be small animals in dark recesses such as cracks in boards or corners of cupboards. On the bench, on your clothes and in the air there would be many small invisible animals called bacteria. And what about the air itself? It is a very important part of our environment. Experiment 2.1 attempts to find out something about the air in your room.

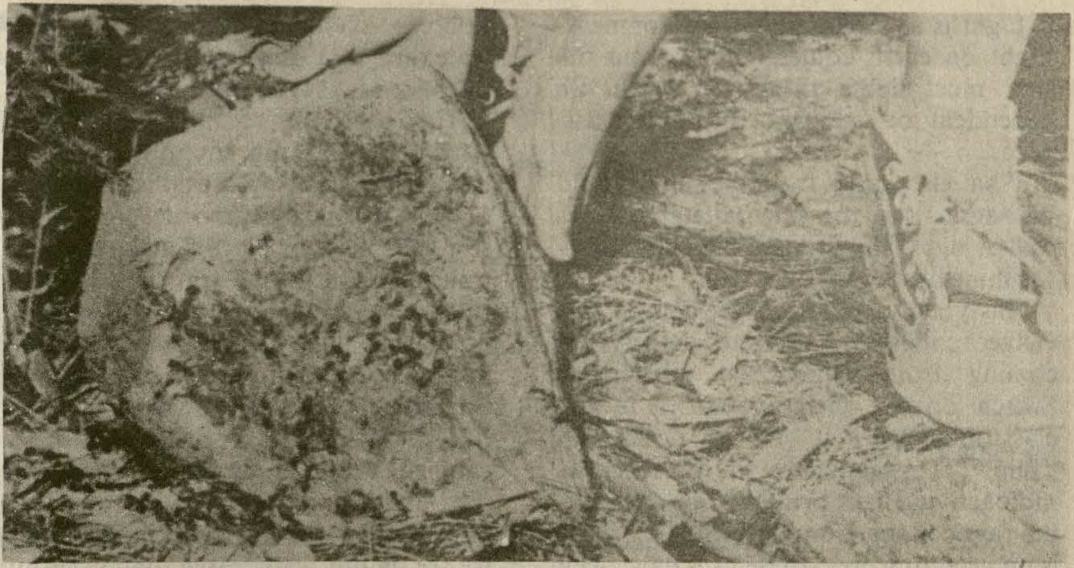


Figure 2.1: An ants' nest exposed by lifting a rock. Ants live in highly organized communities: each member has a particular job to do. Ants become very active when disturbed in this way. What are they setting out to do?

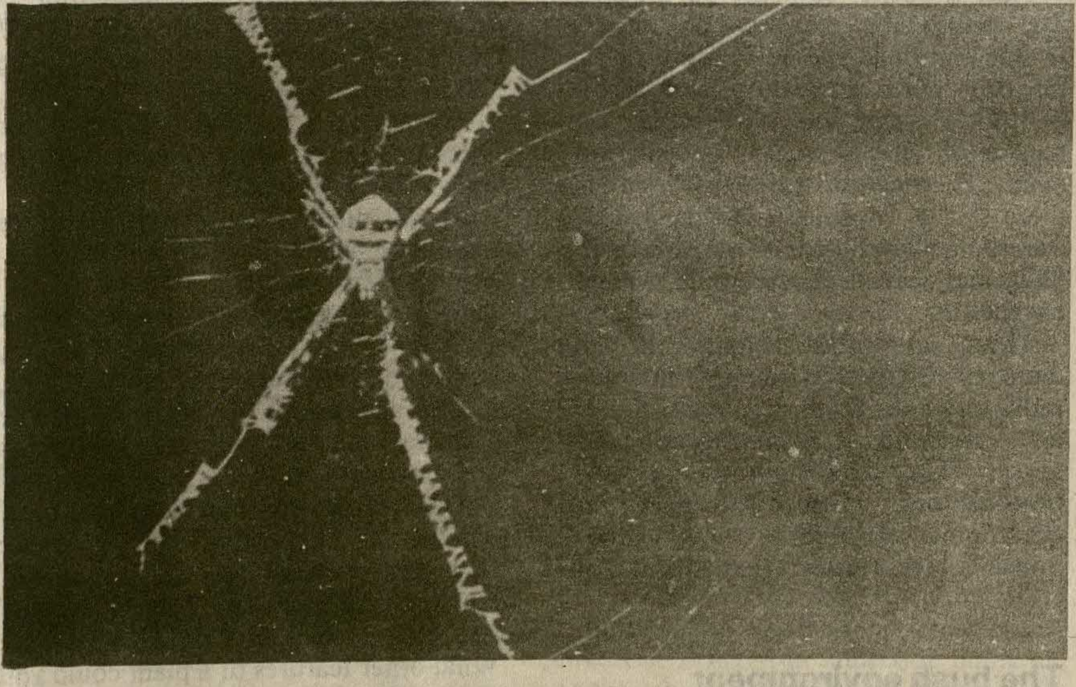


Figure 2.2: The St Andrew's Cross spider. This remarkable spider strengthens its web by weaving thick webbing in the form of a cross. The male is only one-third the size of the female and has a very uncertain existence: it may be eaten by the female after mating.

Light is also part of our environment. Light on earth comes mainly from the sun; most living things on earth are dependent on sunlight for their existence.

What else comes from the sun? Would you agree that the sun radiates heat as well as light? Experiment 2.2 shows how sunshine heats a thermometer.

Has your school a Geiger counter? A Geiger counter is used to detect rays coming from radioactive substances. Switch on the Geiger counter in the classroom. Does it give an occasional "blip"? This indicates the presence of radioactivity. It is probably due to gamma rays coming from outer space. There is no need to worry; these rays have been striking the earth for millions of years. They are harmless because there are so few of them.

Place a pocket compass on a bench. The needle will probably swing from side to side and finally come to rest pointing magnetic north and south. Experiment 2.3 is to help you understand that magnetism also is part of our environment. To describe magnetism, we say there is a magnetic field in the classroom. This field is all over the earth. Ships and aircraft depend on it for their navigation.

There are other things still undiscovered in the classroom. You need a radio set to detect them. Radio stations are constantly transmitting through space. There must always be radio transmissions passing through the classroom. Something about these transmissions is tested in experiment 2.4.

The bush environment

A walk through the bush is enjoyed by most people, especially those who have hobbies such as photography, bird-watching, map-reading or hiking, or are interested in, say, native plants.

The bush environment is different from the classroom environment. However, in the bush we are still in the midst of light and heat from the sun. And we still have also the earth's magnetic field, transmissions from radio and television stations and traces of radioactivity.

In the bush almost everything is natural; there are very few artificial (manufactured) things. Most of the artificial things you see will probably be rubbish dropped along the track by previous walkers.

Suppose we attempt to classify things we see on our walk. How shall we group them? Obviously metallic or non-metallic will be no good as a classification scheme. The only metallic things will be litter, or other man-made objects such as guard rails. Living or non-living? The non-living things are the rocks, the soil, water, and dead animals and plants. However, both the soil and the water contain large numbers of minute living things. (See figure 2.3.)

As we think about it, we begin to realize the bush is an environment teeming with living things.

Living things may be sorted into two groups — animals or plants. Humans, kangaroos, kookaburras, snakes, fish, spiders and worms are all animals. The gum tree, the wattle, the boronia, ferns and even moss are plants.

The best time to observe the variety of plants is in the spring when they are flowering. One of the easiest ways of identifying a plant is by its flower. Of course, not all plants produce flowers. What other features of a plant could you use for identification?

There are many different animals in the bush. Some of you may be interested

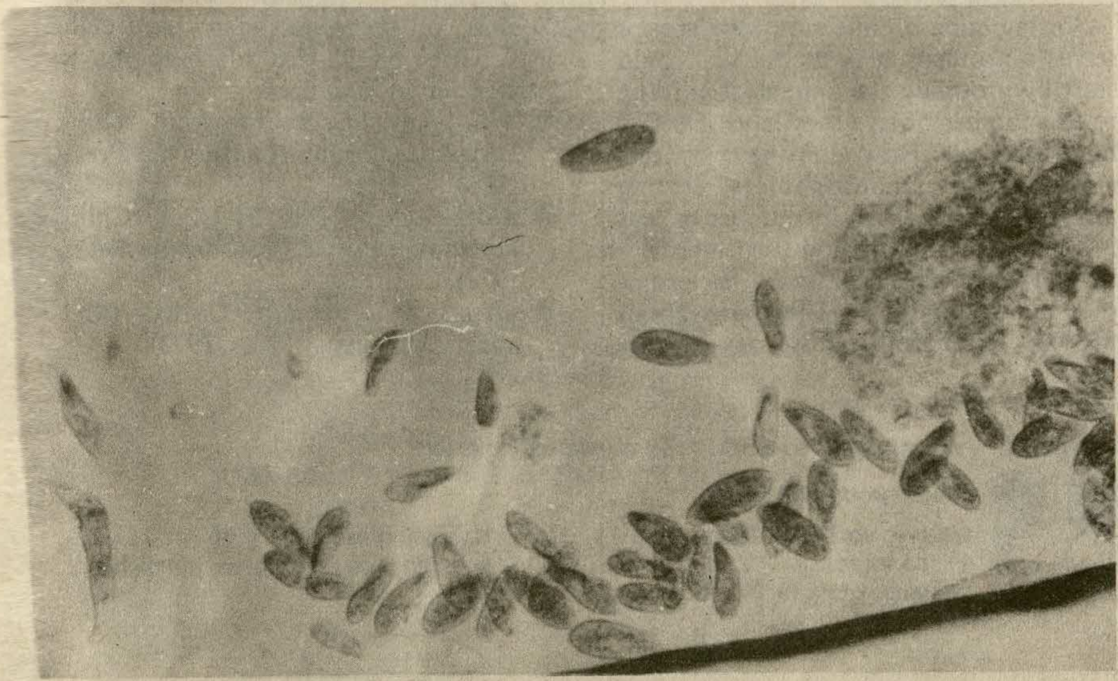


Figure 2.3: A microphotograph of a drop of pond water. The dark line across the bottom right-hand corner is the edge of the microscope slide. Most of the animals in this photo are paramecia: they seem to be moving towards this edge. Why? The animal in the bottom left-hand corner is a rotifer.

in birds. If you are, you will need a suitable handbook such as *Common Australian Birds* by A. and S. Bell (Oxford University Press, 1970), and perhaps a pair of binoculars. Other useful books are *Bird Life* by Ian Rowley (Collins, 1975), *Every Australian Bird Illustrated* (Rigby, 1975), and *Birds of Australia* by J. D. MacDonald (Reed, 1973).

One of the most interesting ways to explore bushland is to look under stones, pieces of wood, bark and heaps of leaves. In these places you will find a variety of small animals quite different from the animals we usually think of, such as birds, kangaroos, fish and snakes. Most of these little animals are without backbones. They include worms, centipedes, millipedes, spiders, slaters and beetles.

Make a collection of these small animals — take only one of each different kind. Always return the rock or piece of wood to its original position after looking beneath it. To help make your collection you will need:

- a small hand-fork
- a pair of fine-pointed tweezers
- a small soft brush
- several small stoppered plastic tubes
- several screw-top bottles.

Brush the animals into the container with the brush or pick them up with the tweezers. Bring your collection home or to the school laboratory. If you need to kill any animals, drop them into a small container of methylated spirits.

Sorting such a collection into groups seems a problem at first. But you could start by grouping the animals according to the number of legs they have. Do any have four legs? How many have six legs, eight legs, more than eight legs? Sorting animals according to the number of legs is a classification method used by scientists. The six-legged animals, for example, are the insects. There are about 850 000 different kinds of insects. Spiders, on the other hand, have eight legs. Three books that will help you to name your animals are:

- *Australian Insects* by John Child, Periwinkle Books (Lansdowne Press, 1976)
- *Australian Spiders* by John Child, Periwinkle Books (Lansdowne Press, 1977)
- *Insects of Australia*, CSIRO (Melbourne University Press, 1973).

EXPERIMENT

2.1

How long does a candle burn inside a glass jar?

Each group will need:

- two small "birthday cake" candles
- large glass jar
- small glass jar
- open dish (aluminium pie dish)

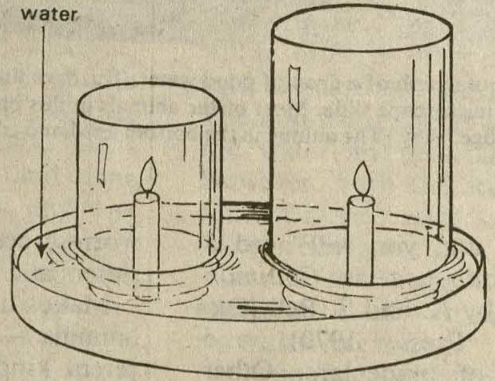


Figure 2.4: How long does a candle burn under a glass jar? Does it depend on the size of the jar?

What to do

- Mark two spots in the bottom of the dish about 10 cm apart.
- Light the candles and allow wax to drip on the two spots. Stand the candles upright in the molten wax. (See figure 2.4.)
- Pour water into the dish to a depth of about 3 cm.
- Stand a jar over each candle. Watch what happens to the flame and the water level in each jar.

Questions

2.1 Do the candles continue to burn until they have completely burnt away?

2.2 When the two candles stop burning, are the water levels in the jars the same as they were at the beginning?

2.3 If there is a difference, what might be the cause of the difference?
2.4 Why did one candle go out before the other?

EXPERIMENT 2.2

How much hotter is sunshine than shade?

Each group will need:

- two 100°C thermometers
- piece of cardboard

What to do

- Place a thick exercise book on a level surface in a sunny position.
- Place the two thermometers side by side on the book about 5 cm apart. Read the temperature on each thermometer.
- Cover the bulb of one thermometer with a piece of cardboard folded so that it does not touch the bulb.
- Read the temperature on each thermometer at minute intervals for about ten minutes.
- Record your readings as follows:

Time elapsed	Temperature	
	Thermometer in sunshine	Thermometer in shade
0 min.	°C	°C
1 min.		
2 min.		

Questions

2.5 Are the temperatures on the two thermometers the same at the end of ten minutes?
2.6 If they are not the same, what is the cause of the difference?
2.7 Name two sorts of rays that come from the sun.

EXPERIMENT 2.3

Investigating magnetism

Each group will need:

- pair of bar magnets
- two heavy iron nails
- two pieces of thick copper wire
- piece of aluminium
- thin thread
- piece of paper
- stainless steel spoon
- metre rule, or equivalent length of wood

What to do

- Look at your pair of magnets. Can you see a special mark on one end of each magnet? Place one magnet on a page of your book. Bring the second magnet up close to the first, as shown in figure 2.5. What happens?

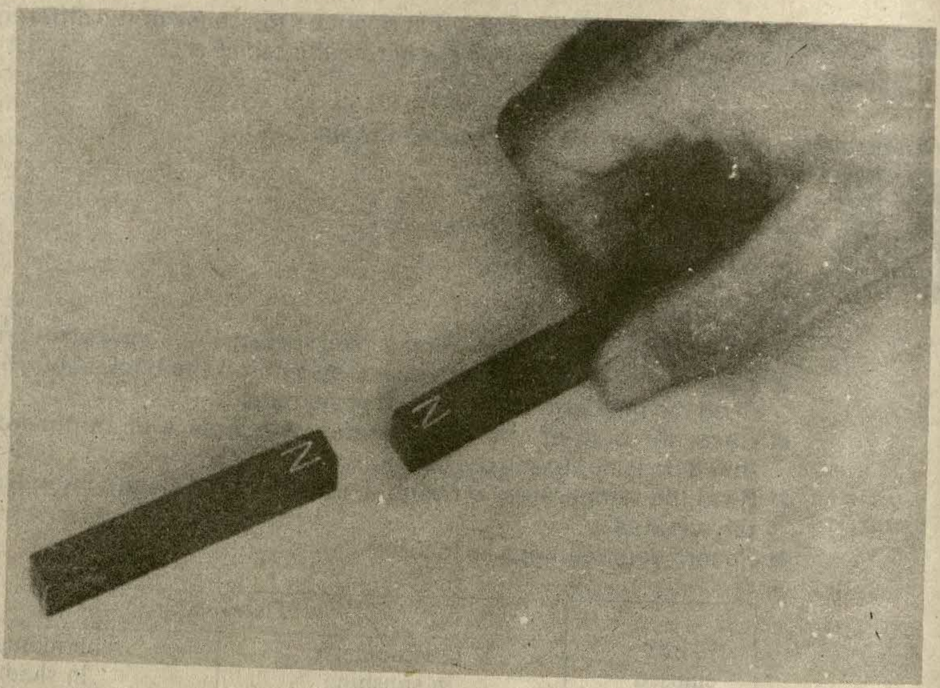


Figure 2.5: What happens when the like poles of two bar magnets are pushed together?

Now turn one magnet around and repeat the test. The ends of a magnet are called its poles. Would you agree that it is only unlike poles that attract? Like (similar) poles repel one another.

- Hold a magnet near pieces of different materials. What materials are attracted to the magnet? Where is the force of the magnet strongest?
- Hold a nail near a magnet that is lying on your book. This time the magnet moves. Why?
- Suspend a magnet with cotton thread, as in figure 2.6. Choose a position well away from iron fittings and other iron objects. What happens to the magnet? Does it align itself in a north-south direction?

Check with other class groups to see if their magnets point in the same direction as yours. Why was it necessary to keep the magnet away from iron objects?

Questions

2.8 What does the last part of experiment 2.3 tell you? Is there a magnetic field in the classroom?

2.9 Draw a diagram showing the correct way to store a pair of magnets. Your teacher will help you here.

2.10 Examine a pocket compass. What is it made of? Why? When using the compass you must keep it away from iron objects, such as pocket knives, billy cans and jam tins. Why?

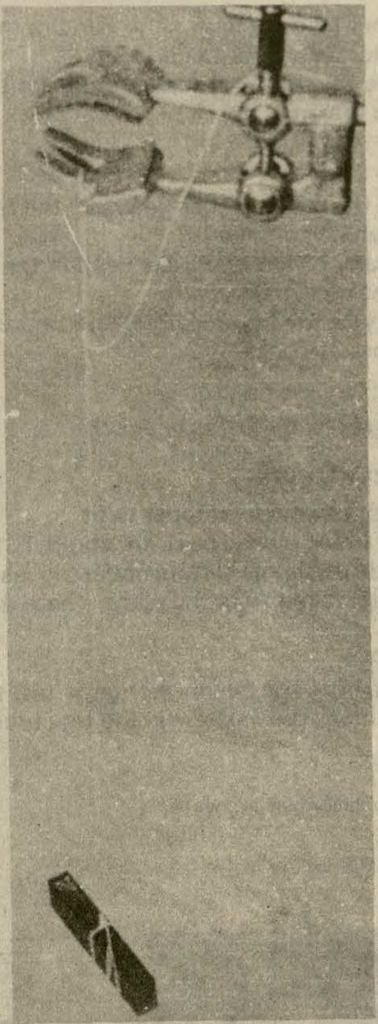


Figure 2.6: A simple compass can be made by suspending a magnet by a thread. The clamp supporting the magnet is made of aluminium. Why not use an iron clamp?

EXPERIMENT

2.4

Do cardboard, aluminium and iron absorb radio transmissions?

Each group will need:

- small transistor radio
- cardboard shoe box (with lid)
- iron biscuit tin (with lid)
- aluminium cake container (with lid)

What to do

- Tune into a radio station on the transistor. Turn the volume down until you can just hear the station.

- Place the radio set first in the iron tin, then in the cardboard box and finally in the aluminium container.
- Listen to the radio in each container with the lid lifted slightly and your ear close to the opening.

Questions

2.11 Did the volume change when the radio was placed in the containers? In which containers?
2.12 Do any of the materials used in these containers tend to absorb radio transmissions?
2.13 Do you think wood, bricks, concrete or glass are absorbers of radio transmissions?

EXPERIMENT 2.5

Do slaters prefer darkness or light?

Each group will need:

- large test tube with stopper to fit
- piece of black plastic or cloth, about 10 cm square
- two or three slaters (found under pieces of wood in a moist environment)
- a little soil taken from the place where the slaters were found

What to do

- Spread a little soil evenly along the test tube.
- Place two or three slaters in the test tube and fit the cork.

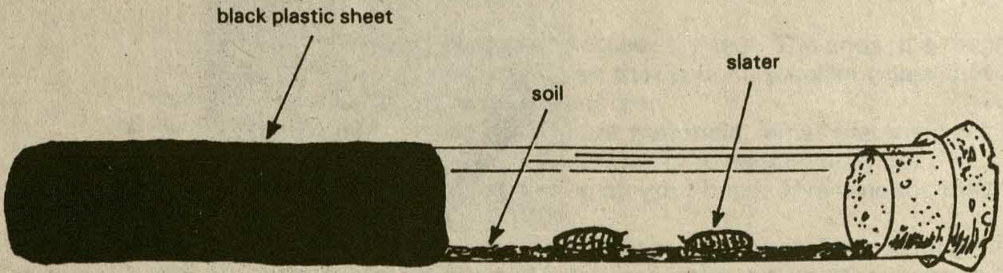


Figure 2.7: Do slaters prefer the light or the dark?

- Place the black material over one half of the tube. Some groups should place it over the corked end and the remainder over the glass end.
- Observe what happens after twenty minutes.

Questions

2.14 Did the slaters move along the tube?
2.15 If the slaters moved, which way did they go?
2.16 What would you say caused them to move — the soil, the light or the cork?
2.17 What do you conclude about the habitat slaters prefer?

Spelling list

aluminium
artificial
bacteria
centipede
classify
compass
dependent
environment
habitat
identify
interval
metallic
millipede
natural
original
radiate
repel
temperature
thermometer
transmission

More questions

2.18 Some people put the TV aerial in the roof of their home, beneath the tiles. Would TV reception be affected if the roof were lined with paper covered with aluminium sheeting?

2.19 Have you ever seen a "daddy-long-legs" in your home? Is it a spider or some other sort of animal? How many legs has it and how many parts are there in its body?

2.20 Have you ever had an apple with a grub in it? What are these grubs? Where do they come from and what do they grow into? Describe the life cycle of the fruit fly.

2.21 Spiders are most interesting animals. For example, they digest their food before eating it. The female of one kind of spider eats the male after mating! (What is a "black widow"?)

How do spiders spin their webs? Where do they lay their eggs? Your library will have a book on spiders — see what other interesting things you can find out about them.

2.22 Flies seem to disappear during the winter. Where do they go? What happens to them?

2.23 Both silverfish and moths can damage clothes stored in cupboards. But is it the silverfish and the moth that actually eat the clothes? What does the eating?

2.24 A fully grown garden snail is usually about four or five years old. It is only active during damp weather. How does it survive during dry weather? It does a very interesting thing. What is it?

3

Making measurements

People are constantly making measurements. Some measurements need only be approximate. A cook, for example, measures out cups of flour, teaspoons of sugar and pinches of salt. An engineer, on the other hand, might be expected to measure the diameter of a steel shaft to within one thousandth of a centimetre.

Accuracy is important when things are manufactured. Think of a motor car assembly line. The parts are made in one factory and put together in another. Take pistons as an example. All pistons manufactured must be as close as possible to the same size. Otherwise the pistons won't fit properly into the engine as it is being assembled.

Accuracy in measuring depends on accurate rulers and gauges. These are only accurate because the machines that make them can be checked against a standard metre kept at the National Measurements Laboratory. (See figure 3.2.)

Imagine what it was like years ago, when there were no standards kept in laboratories. A common unit for measuring length was the *cubit*. This was the length of the forearm from elbow to fingertip. The *span* and the *pace* were also used to measure length. And an early traveller might have described two towns as being a day's march apart.

About two hundred years ago the King of France decided to establish a uniform,

Figure 3.1: Accuracy in industry. Parts for motor vehicles must be accurate in every detail. Here an operator at the Ford plant at Geelong is checking the accuracy of a machine that automatically grinds the main engine shaft of a Ford Falcon. (Photo courtesy Ford of Australia)

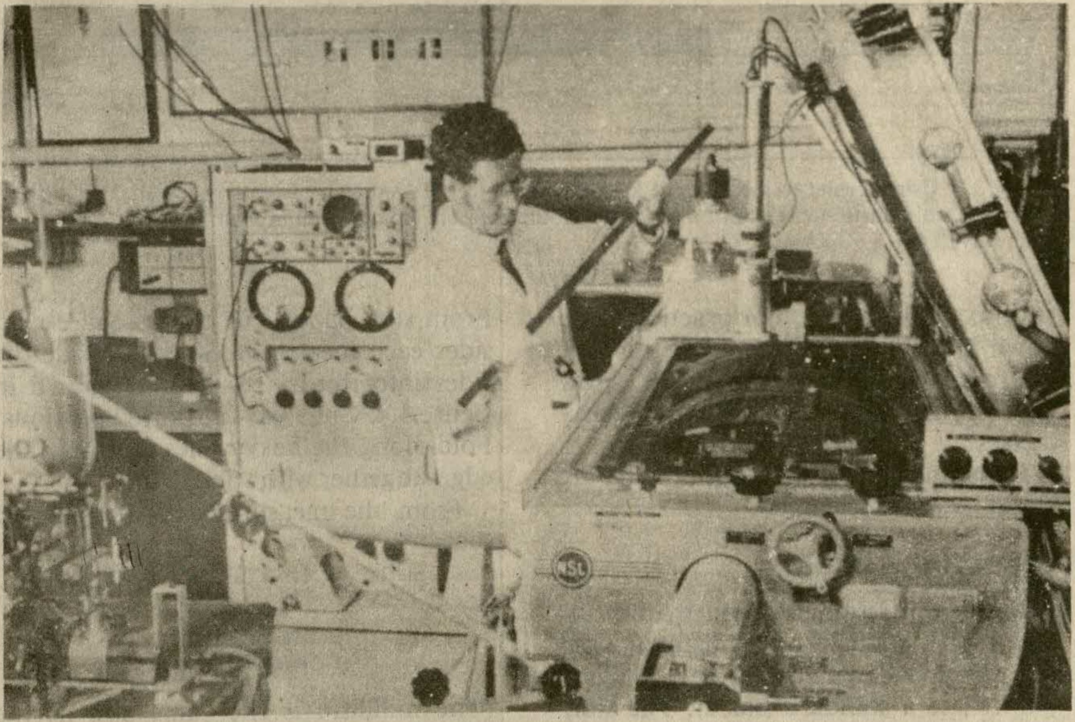


Figure 3.2: Australia's copy of the standard metre. The man is about to place it in a special machine to check that its length hasn't varied with use. (Photo courtesy National Measurements Laboratory)

and more accurate, measuring system. A committee was appointed and after much discussion it chose one ten-millionth of the distance from the equator to the North Pole as the standard. The committee called this standard of distance the *metre*. A metal bar was then made that measured one metre at 0°C. This bar, called the standard metre, is kept in Paris.

It would be very awkward if every country in the world had to refer to a standard kept in Paris. Therefore, copies of the standard have been made and sent to many parts of the world. It is one of these copies that is kept at the National Measurements Laboratory in Sydney.

Look at the metre ruler in your laboratory. Notice that it is divided into 100 equal parts, called centimetres. Each centimetre is divided into 10 equal parts, called millimetres.

$$1 \text{ centimetre} = \frac{1}{100} \text{ metre}$$

$$1 \text{ millimetre} = \frac{1}{1000} \text{ metre}$$

When using a ruler to measure the length of an object, it is best to follow these hints:

- Avoid measuring from the end of the ruler if the scale starts at the end.
- Turn the ruler onto its edge.
- Have your eye directly above the section of the ruler where you are making your reading.

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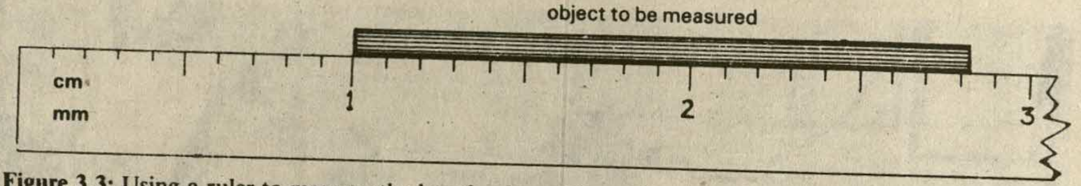


Figure 3.3: Using a ruler to measure the length of an object. This drawing is enlarged to make it clearer. When the scale starts at the end of a ruler you should measure from a point in from the end. Can you explain why?

Look at figure 3.3. For practice, write down the length of the object in the figure to the nearest millimetre. How would you write this length in centimetres?

Experiments 3.1, 3.2, 3.3, and 3.4 are about measuring lengths.

Measuring liquids

Oil companies sell crude oil by the *barrel*. Barrels come in many different sizes but, as you can imagine, the oil companies use a standard barrel. The standard barrel is based on the *litre*. The litre, in its turn, is based on the metre.

You can quickly make a container that holds one litre by referring to figure 3.4. From stiff paper, cut out a square with sides each measuring 30 cm. Divide the sides into thirds. Rule up as shown in figure 3.4. Cut away the dotted portions. Fold along the heavy lines and hold the edges together with sticky tape.

From the measurements we can see that:

$$\begin{aligned} 1 \text{ litre} &= 10 \times 10 \times 10 \text{ cubic centimetres } (\text{cm}^3) \\ &= 1000 \text{ cm}^3 \\ &= 1000 \text{ millilitres (mL)} \end{aligned}$$

(The millilitre is the same size as the cubic centimetre.)

$$1 \text{ millilitre (mL)} = \frac{1}{1000} \text{ litre (L)}$$

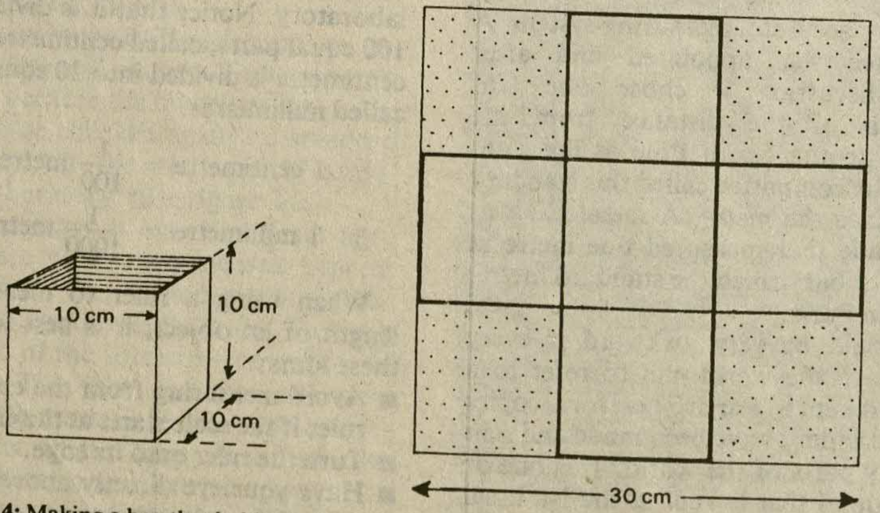


Figure 3.4: Making a box that holds one litre. Cut out a square of stiff paper, with each side 30 centimetres long. Remove the portions shown dotted in the diagram, and fold along the heavy lines.

Figure 3.5 shows how to read the volume of water in a measuring cylinder. The curved surface of the water makes it awkward to read the scale. This curved surface is called the meniscus. The manufacturer marks the measuring cylinder so that the correct reading is obtained when you read to the bottom of the meniscus.

Use the following rules:

- See that the measuring cylinder is upright.
- Have your eye level with the bottom of the meniscus.
- Read to the nearest scale mark.

Experiments 3.5 and 3.6 ask you to measure volumes.

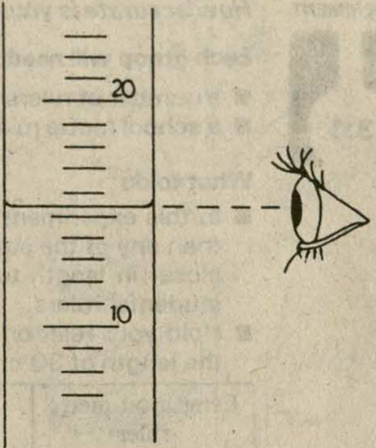


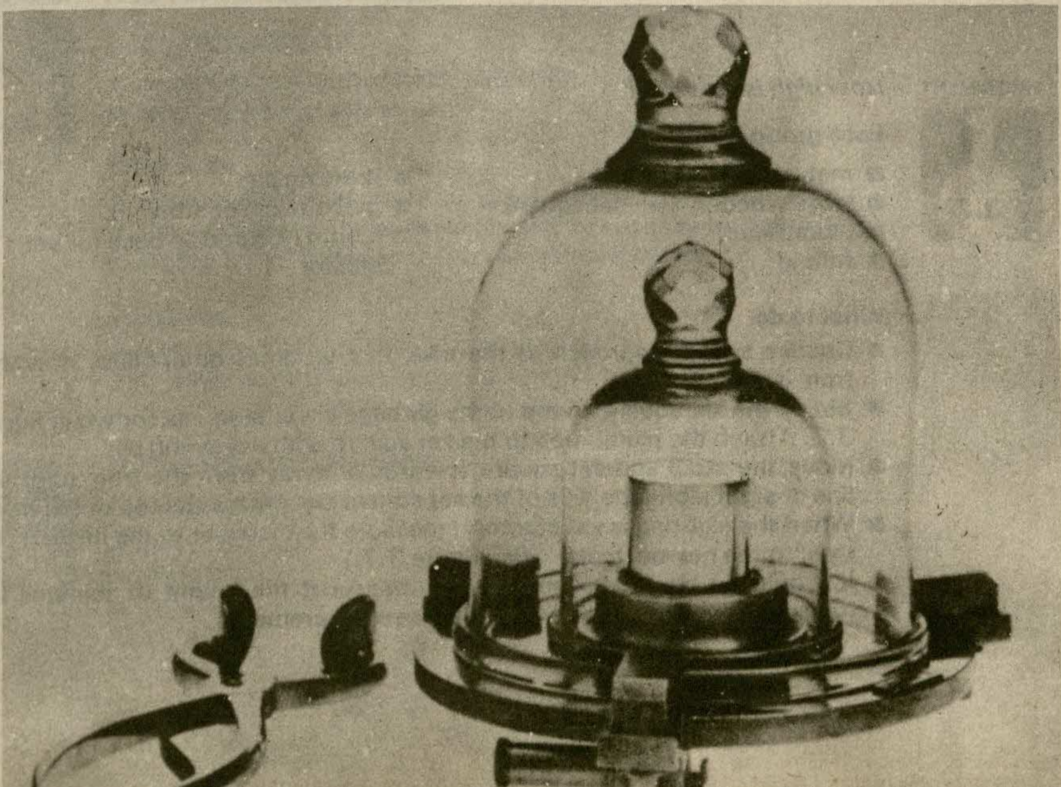
Figure 3.5: Reading the volume of water in a measuring cylinder to the nearest scale mark.

Weighing

The standard for weighing is the *kilogram*. The kilogram is the weight of a litre of water. A standard kilogram is kept at the National Measurements Laboratory in Sydney. (See figure 3.6.)

Experiment 3.7 is a problem involving weighing.

Figure 3.6: Australia's copy of the standard kilogram. Notice the special containers used to store it and the padded tongs used to lift it. (Photo courtesy National Measurements Laboratory)



EXPERIMENT 3.1

How accurate is your ruler?

Each group will need:

- a number of rulers
- a school metre ruler

What to do

- In this experiment we shall assume that the metre ruler is more accurate than any of the students' rulers. What this means is that the metre ruler is closer in length to the standard metre than is a metre marked off with students' rulers.
- Hold your ruler on its edge on the metre ruler. Using your ruler, measure the length of 30 cm of the metre ruler. Record your results as follows:

Length on metre ruler	Reading for this length on student's ruler	Difference
30 cm		

Questions

3.1 Did you find any difference between the metre ruler and students' rulers? What was the biggest difference? Did you find that the most expensive ruler was the most accurate?

3.2 Try to obtain a dressmakers' tape. Check it for accuracy.

3.3 Comment on the statement "Providing you know how to use it properly, a good ruler always gives you the exact length".

EXPERIMENT 3.2

How high is that tree?

Each group will need:

- metre ruler
- large wooden 45° set square
- plumb-bob
- thread
- drawing pin
- garbage bin or stool
- length of wood as base for set square

What to do

- Choose a level approach to the tree, that is, don't be uphill or downhill from it.
- Set up the set square on top of the garbage bin or stool, as shown in figure 3.7. Attach the plumb-bob to the set square with a drawing pin.
- Move the stool and set square towards or away from the tree, until the line of sight along the side of the set square just grazes the top of the tree.
- When the sighting is satisfactory, measure the distance to the base of the tree, to the nearest metre. (See figure 3.7.)
- It would be best if several groups measured the height of the tree independently. Take an average of these measurements.

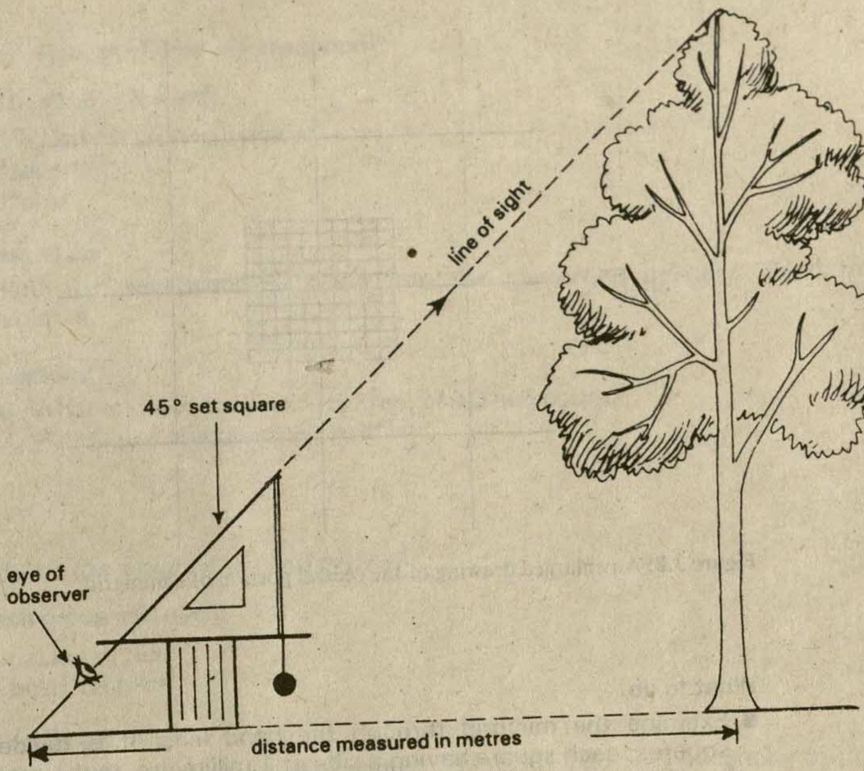


Figure 3.7: Measuring the height of a tree.

EXPERIMENT

3.3

How thick is a sheet of paper?

Each group will need:

- exercise book with at least 100 sheets
- ruler marked in millimetres

What to do

- Count out 100 sheets of the exercise book.
- Ask your partner to squeeze the sheets together as tightly as possible.
- Measure the thickness to the nearest millimetre.

Questions

3.4 What is the thickness of 100 sheets?
3.5 What is the thickness of one sheet?

EXPERIMENT

3.4

What is the thickness of a hair?

Each group will need:

- strand of hair
- minigrid
- hand lens

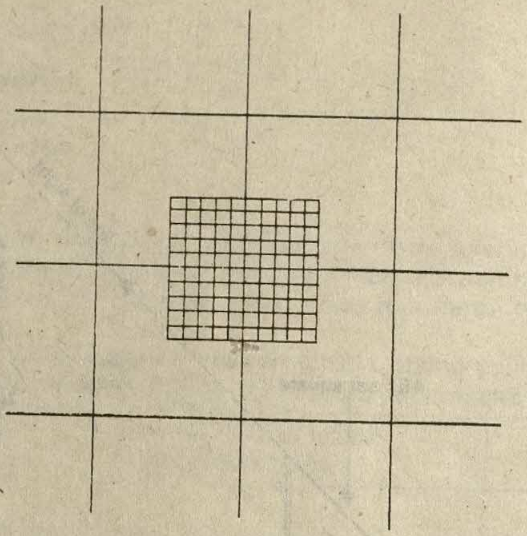


Figure 3.8: An enlarged drawing of the central portion of a minigrid.

What to do

- Examine the minigrid through the hand lens. It is divided into 100 squares, each square having a side of 1 millimetre. In the centre there is a small part divided into 100 tiny squares. Each of these tiny squares has a side of only 1/10 millimetre.
- Hold a hair firmly across the centre of the minigrid and estimate the thickness to the nearest tenth of a millimetre.

EXPERIMENT

3.5

How many cups in a litre?

Each group will need:

- litre measuring cylinder
- cup
- water

What to do

- Pour cups of water into the measuring cylinder, counting them as you do so.
- Keep adding cups of water until you reach the litre mark. If you have less than half a cup left over, count this as a complete cupful in the measuring cylinder. Do not count it if you have more than half a cup left over.
- How many cups (to the nearest cup) are there in a litre?

EXPERIMENT 3.6

How many millilitres in a teaspoon?

Each group will need:

- 100 ml measuring cylinder
- teaspoon
- water

What to do

- Pour ten teaspoons of water into the measuring cylinder. Read the volume.

Questions

3.6 What is the volume, in millilitres, of 10 teaspoons?
3.7 What does one teaspoon hold?

EXPERIMENT 3.7

What is the weight of a grain of rice?

Each group will need:

- packet of rice
- beam balance

What to do

- Each member of the group should count out 100 to 140 grains of rice. Count them out into heaps of 20 until you have the number required.
- Place the grains on the balance and weigh them to 1/10 of a gram, if possible. How accurately you can weigh will depend on the type of balance you use.
- Calculate the weight of one grain of rice.

Measurement

1. The standard of length is the metre.
2. Measurements are made by making comparisons with a standard.
3. Measurements are never completely accurate.
4. 1 centimetre (cm) $= \frac{1}{100}$ metre (m)

   1 millimetre (mm) $= \frac{1}{1000}$ metre (m)
5. 1 litre (L) = 1000 cubic centimetres (cm^3)

   1 millilitre (mL) $= \frac{1}{1000}$ litre (L)
6. The standard for weighing is the kilogram.

Spelling list

accuracy
centimetre
committee
cylinder
decision
diameter
engineer
gauge
kilogram
litre
measurement
meniscus
millilitre
minigrid
plumb-bob

Things to do

3.8 What is your height? Measure it by standing against a wall and asking your partner to place a ruler horizontally on your head. What is the average height of the class? Are the girls taller than the boys?

3.9 How big is the biggest ant you can find? Kill the ant by dropping it into a little methylated spirits. Use a ruler marked in millimetres to estimate the ant's length.

3.10 How big is a drop of water? Count a large number of drops into a measuring cylinder.

3.11 How wide is the groove on a gramophone record? Have a class discussion about the best way to count the grooves.

3.12 What is the volume of the classroom in cubic metres? How many cubic metres of air does this give to each person in the room?

3.13 What is the volume of a stone? Pick a small one and drop it into a measuring cylinder containing some water.

Test yourself (chapter 3)

Several answers are suggested for each of the first four questions of this test. Choose the best answer to each question and write its letter in your workbook. Answer all parts of question 5.

1. The standard for the measurement of length is the:
   (a) litre
   (b) metre
   (c) kilogram
   (d) centimetre.
2. The viewing positions for the most accurate measurement in figure 3.9 are:
   (a) both x and y
   (b) both y and z
   (c) both z and x
   (d) y only.
3. Measuring the length of an object with a metre ruler will give you:
   (a) its exact length
   (b) its length with no more than a metre error
   (c) its length with no more than a centimetre error
   (d) its length with no more than a millimetre error.

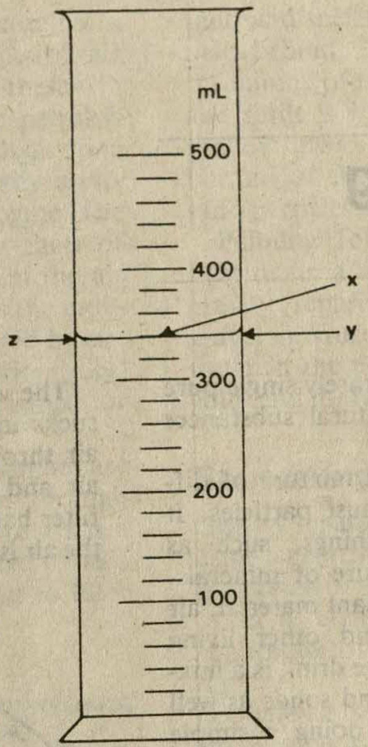


Figure 3.9

A person interested in finding the average weight of a nail found that 100 of these nails weighed 200 grams. From this he concluded that one nail weighed:
(a) exactly ½ gram
(b) exactly 2 grams
(c) approximately ½ gram
(d) approximately 2 grams.

Look at figure 3.9.
(a) How much water is in the cylinder?
(b) How much more water would have to be put into the cylinder to raise the level by one scale mark?
(c) How much water would have to be added to raise the level to the highest scale mark?

4

Separating mixtures

Natural substances are rarely single pure substances — most natural substances are mixtures.

For example, air is a mixture of different gases and fine dust particles. It also contains living things, such as bacteria. Soil is a mixture of minerals, rock particles, rotting plant material, air and water, bacteria and other living things. Even the water we drink is a mixture, containing gases and solids as well as water. You will be doing a simple analysis of tap water in experiment 4.1.

Throughout history, people have worked to separate mixtures. For example, thousands of years ago copper ores were separated from other rock material so that copper could be extracted. Have you ever seen pictures of people in Indian villages separating grains of wheat from the husks? This is another example of separating a mixture. In Australia this separation is done by a harvesting machine.

This chapter is about some of the methods used to separate mixtures.

Filtration

Filtration is a method of separating solid particles from a liquid or a gas. The separation is made by passing the mixture through a screen fine enough to retain the solids.

The vacuum cleaner uses filtration. It sucks up dust by pumping a current of air through the carpet. The mixture of air and dust is then passed through a filter bag, which collects the dust before the air is pumped back into the room.

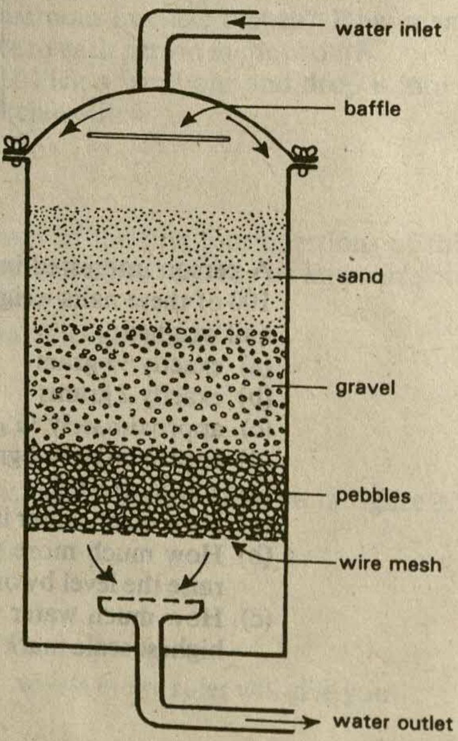


Figure 4.1: A filter. The sand is the actual filter; the gravel and pebbles support it. Periodically the mud that has collected is flushed out of the sand by reversing the flow of the water for a short time.

The motor car engine contains a number of filters. A car uses petrol, air and oil. Dust or grit in any of these will cause wear in the engine. The petrol is filtered by pumping it through fine gauze. The air filter is generally a circular container on top of the engine. The engine sucks in air through a sheet of paper or layers of wire mesh in the air filter. The oil, which lubricates the moving parts of the engine, is filtered by circulation through a gauze. Periodically, all these filters are either cleaned or replaced.

Most town and city water supplies are filtered by passing the water through beds of sand and gravel. Figure 4.1 is a diagram showing a small filter of this type, which could also be used to filter the water of a swimming pool.

Gravity separation of mixtures

How may clean sand be recovered from a mixture of sand and soil?

A small quantity of this mixture is placed in a screw-top jar. Some water is added, the top is screwed on and the mixture shaken. When the jar has stood for a short time, we observe that the sand particles, which are heavier, have settled to the bottom, while most of the soil remains suspended in the water. This suspension of soil particles is poured off into a beaker. More water is added to the jar and the process is repeated. The jar then contains mostly sand and the beaker mostly soil in suspension. The sand may then be emptied out of the jar and dried in the air.

This sort of gravity separation occurs in nature — for example, on some beaches. Valuable heavier minerals, such as rutile, become concentrated in particular parts of the beach as the receding waves carry back with them the lighter sand and shells, leaving the heavier particles behind. The same process is used in the mining of rutile. The mixture of sand and rutile is washed through a series of shallow dishes. The rutile settles to the bottom of the dishes, while the lighter sand particles are washed away.

Panning for alluvial gold in sandy streams is a method that depends on gravity separation. As the sand and gravel mixture is swirled around with water in the pan, the heavy particles of gold tend to trail behind.

Separating by centrifuging

Gravity separation may be speeded up by using a centrifuge. Figure 4.2 (next page) is a sketch of a centrifuge.

Let us compare the time taken for a precipitate of barium sulphate to settle out

(a) when it is centrifuged

(b) when it is left to stand.

The precipitate is made by adding some dilute sulphuric acid to a solution of barium chloride in a test tube. Part of the solution with the precipitate in it is centrifuged for about half a minute. The white precipitate completely settles to the bottom in this time. The rest of the precipitate, in the solution that has been left to stand, takes at least half an hour to settle out.

Fresh milk is usually centrifuged before being bottled to separate most of the cream. You have probably noticed some cream as a layer on top of the milk delivered to your home. Let us centrifuge some milk to see if this speeds up the rate at which the cream separates out.

A bottle of milk is up-ended several times to thoroughly disperse the cream. One sample of this milk is centrifuged for about five minutes. A thin layer of

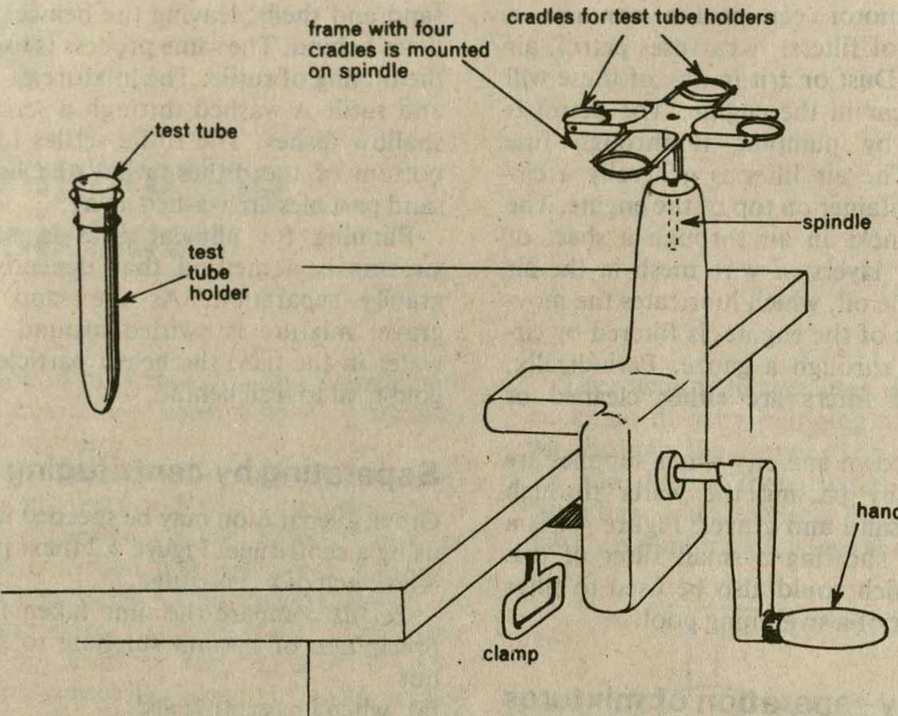

frame with four cradles is mounted on spindle
cradles for test tube holders
test tube
test tube holder
spindle
handle
clamp

Figure 4.2: The centrifuge. The spindle turns about twenty times for each turn of the handle. The holders, which hang vertically when the centrifuge is not in use, are practically horizontal when the handle is turned.

cream forms on the top of this sample. Another sample is allowed to stand. It shows no sign of separation after five minutes. At least half an hour must elapse before a thin layer of cream forms.

Separation by flotation

To illustrate this method we shall separate a mixture of red lead and sand. About 1 gram of red lead is mixed with 20 grams of sand and placed in a small measuring cylinder. About 50 millilitres of water and 20 millilitres of kerosene are added and the mixture is shaken vigorously. Most of the red lead is carried to the top of the vessel by the kerosene froth. This is called froth flotation and is widely used to separate metallic minerals from unwanted rock material. In the industrial process the finely crushed ore is mixed with water and a small amount of special oil. When air is blown through this mixture, the froth from the oil carries the valuable minerals to the top. Separation occurs because the oil is able to thoroughly wet the mineral, which sticks to it and floats with it to the surface.

Evaporation to recover a dissolved solid

Sea water contains dissolved solids. These may be recovered by evaporation of the water in which they are dissolved.

Some sea water is poured into a clock glass set on a beaker of boiling water. The water is kept at the boil so that steam from it will heat the sea water and cause it to evaporate. After some time, only a thin layer of white powder remains in the clock glass. This powder is a mixture of sodium chloride (a white solid) and other substances. Sodium chloride is common salt.

In Whyalla, South Australia, common salt is separated out from sea water by evaporating water from shallow ponds. The energy needed to evaporate the water comes from the sun's rays. Figure 4.3 shows this solar salt works, from which 65 000 tonnes of salt are crystallized each year. Figure 4.4 shows the loading of some of this salt at Whyalla wharves.

Distillation

Distillation is a common method of separating liquids from mixtures. In experiment 4.2 you will use this method to separate water from a mixture of water and copper sulphate.

Distillation can also be used where you have a mixture of two liquids, such as methylated spirits and water. Let us separate such a mixture.

First prepare the mixture by mixing equal volumes of the two liquids. A small sample is tested with a lighted match to see if it will ignite. The remainder is poured into the distillation flask, as shown in figure 4.5 (page 35).

The process depends on the fact that methylated spirits boils much more readily than water; the boiling point of

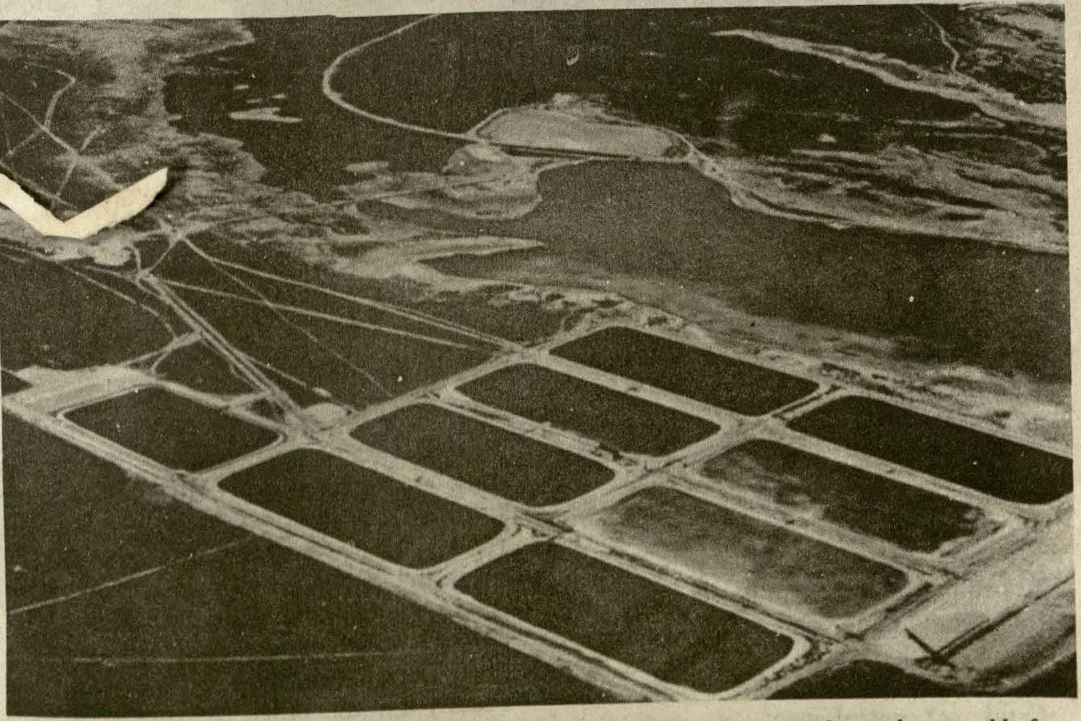


Figure 4.3: Solar salt works at Whyalla, South Australia. Nine crystallizing ponds stand out starkly from the sand, mulga, salt bush and coastal lagoons. (Photo courtesy B.H.P. Ltd)

Figure 4.4: Loading salt at the Whyalla wharves for Australian and overseas markets. (Photo courtesy B.H.P. Ltd)

methylated spirits is about 75°C, whereas that of water is 100°C. The mixture is brought slowly to the boil and a few drops of distillate are collected in the small flask. The distillate will not be pure methylated spirits, but should be much richer than the original mixture. Testing with a lighted match will show this.

What should be done next to make the distillate richer in alcohol?

Crude oil (petroleum) is a mixture of many liquids such as petrol, kerosene and diesel oil. Because each liquid boils at a different temperature, distillation may be used to separate them. Figure 4.6 (page 36) shows how this is done at an oil refinery. The structure is called a fractionating tower because it separates the mixture into its parts, or fractions. The crude oil is boiled at the bottom and vapour rises towards the top. The more readily a liquid boils, the further it rises in the tower before it condenses and is drained off.

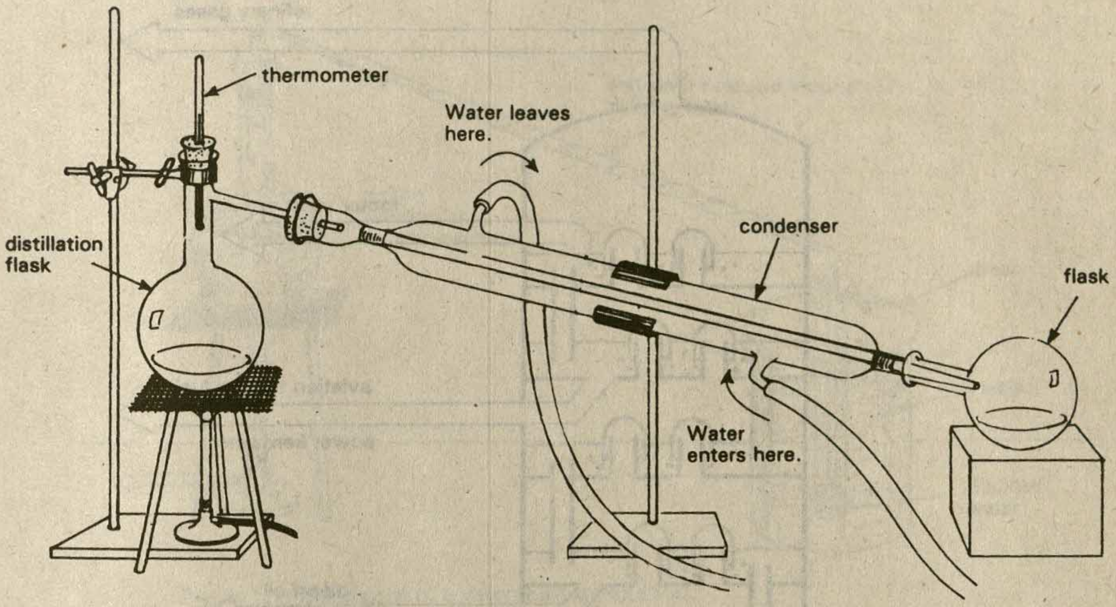


Figure 4.5: Separating methylated spirits from water by distillation.

EXPERIMENT

4.1

Analysing tap water

Each group will need:

- clock glass
- beaker
- gauze
- tripod
- Bunsen burner

What to do

- Almost fill the beaker with tap water and heat it on a gauze with a Bunsen burner. Do you see small bubbles of gas forming in the water? These are bubbles of the air that was dissolved in the water.
- Almost fill the clock glass with tap water and place it on top of the beaker.
- Heat the beaker of water until it boils, and continue to boil the water until the clock glass is dry.

Questions

4.1 Is there any residue on the clock glass?

4.2 If there is, what is its colour? A white residue would probably be mineral salts; a brown residue could be vegetable matter or rust from water pipes.

4.3 Drink some of the boiled water when it is cold. Does it taste different from unboiled tap water? If it does, the difference is due to the air dissolved in unboiled tap water. We say this water is *aerated*.

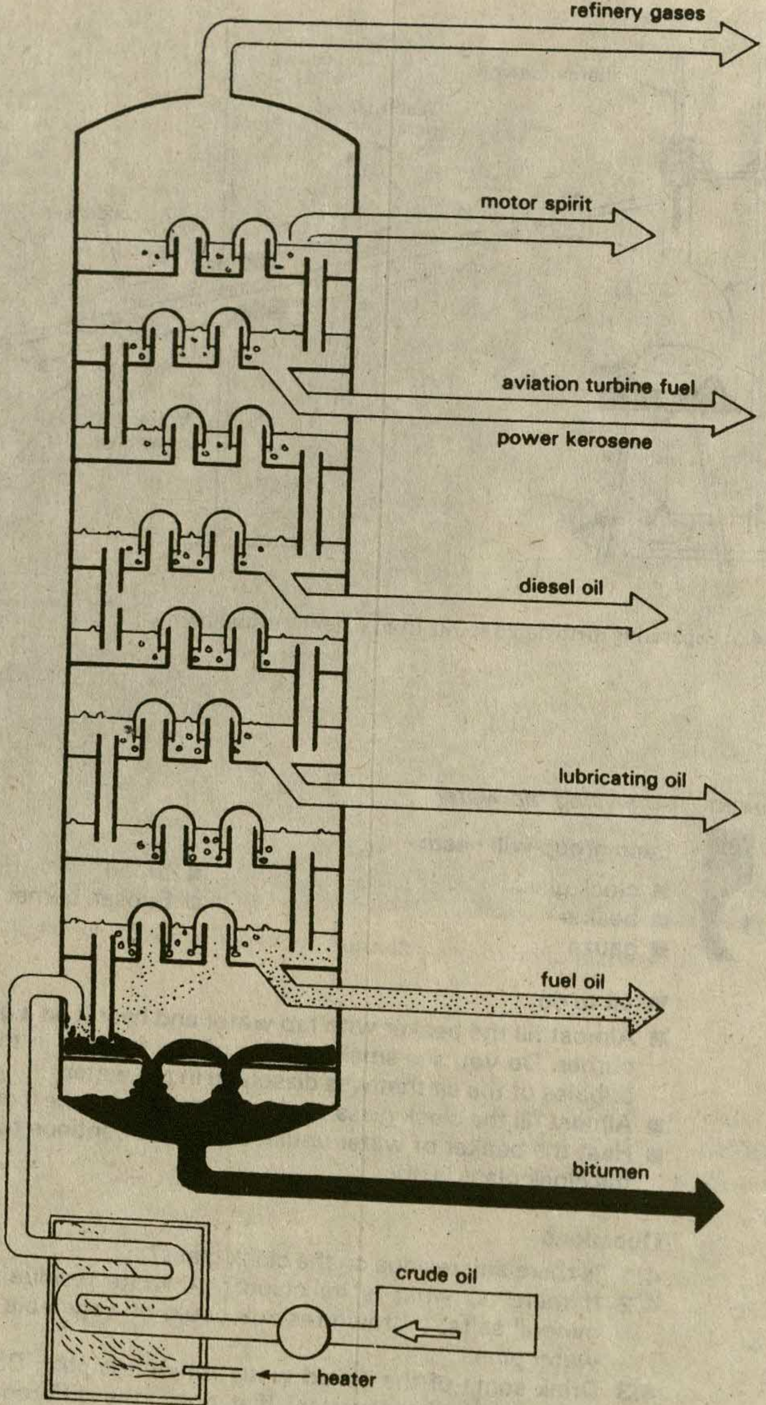


Figure 4.6: A fractionating tower used to separate crude oil into its parts, or fractions.

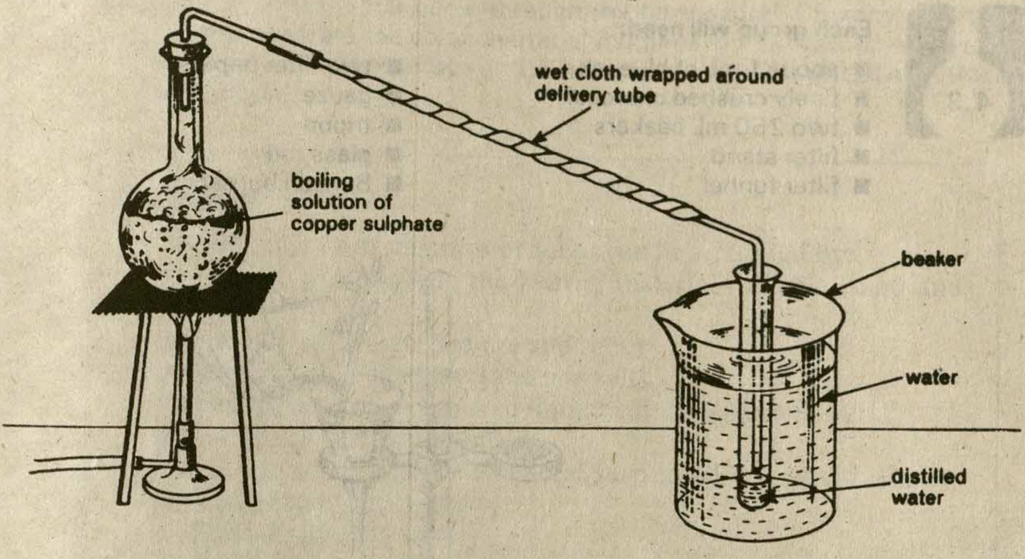

wet cloth wrapped around delivery tube
boiling solution of copper sulphate
beaker
water
distilled water

Figure 4.7: Distillation of copper sulphate solution.

EXPERIMENT 4.2

Obtaining water from a mixture of water and copper sulphate

Each group will need:

- 250 mL flask
- sufficient powdered copper sulphate to cover a 2 cent piece
- stopper
- two pieces of glass tubing (see figure 4.7)
- short piece of rubber tubing
- gauze
- tripod
- Bunsen burner
- strip of rag to wind round tube
- test tube
- beaker

What to do

- Pour about 100 mL of tap water into the flask. Add the copper sulphate and shake to dissolve.
- Assemble the apparatus as shown in figure 4.7.
- Heat the flask gently to boil the blue solution.
- Continue to boil the solution until you have collected 2 or 3 mL of liquid in the test tube.

Questions

4.4 What is the colour of the liquid in the test tube? If it is colourless, can you name it and explain why it is colourless?

4.5 How would you recover the copper sulphate dissolved in the water in the flask?

EXPERIMENT 4.3

Using charcoal to separate ink from water

Each group will need:

- about 1 mL of blue ink
- finely crushed charcoal
- two 250 mL beakers
- filter stand
- filter funnel
- two filter papers
- gauze
- tripod
- glass rod
- Bunsen burner

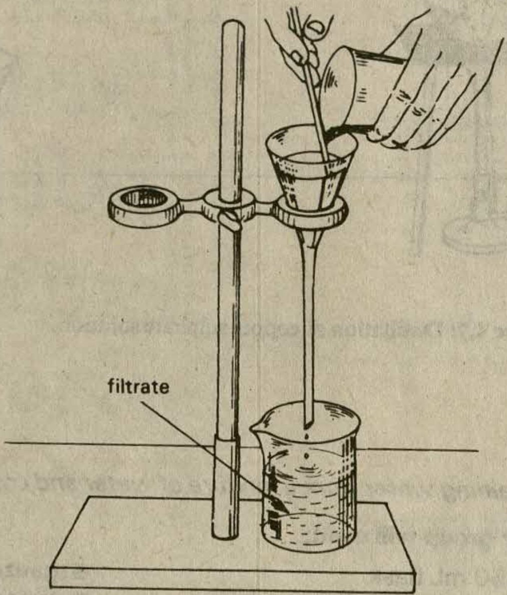


Figure 4.8: Separation of charcoal and water by filtration. The charcoal is retained on the filter paper and the water passes through.

What to do

- Add 4 or 5 drops of blue ink to about 100 mL of water in a beaker.
- Set up the filtering apparatus and test to see whether the filter paper will separate out the colouring matter in the ink. Do this by pouring the ink mixture into the funnel, using a glass rod as shown in figure 4.8.

Question

4.6 Does the filter paper hold the ink? In other words, does colourless water come through the funnel? If it does, what does this show about ink particles?

- Add about 3 teaspoons of crushed charcoal to the filtrate. Place the beaker on a gauze and boil the charcoal-ink mixture for about 5 minutes.
- Allow the mixture to cool a little, then filter it through a freshly folded paper. Again use the glass rod as shown in figure 4.8.

Question

4.7 Did colourless water come through the filter paper? Charcoal is often used to separate the components of mixtures in this way. The ink particles adhere to the surface of the charcoal grains. This process is called adsorption.

Mixtures

1. The ingredients of mixtures of solids can be separated by:
   - washing and allowing the heavier material to settle (sand and rutile)
   - froth flotation (crushed ore and rock)
   - dissolving and filtering (sand and salt).
2. The ingredients of mixtures of liquids can be separated by:
   - distillation (petrol and oil).
3. When a mixture consists of a solid suspended in a liquid, the ingredients can be separated by:
   - filtration (muddy water)
   - centrifuging (creamy milk)
   - adsorption by charcoal (ink and water)
   - allowing the solids to settle (muddy water).
4. Solids can be separated from gases in which they are suspended by:
   - filtration (dust in air).
5. Solids can be separated from liquids in which they are dissolved by:
   - evaporation (salts in sea water).

Spelling list

adhere
adsorption
aerate
alcohol
centrifuge
charcoal
concentration
condense
diesel
distil
distillation
evaporate
filtration
flotation
gas
gases
gravel
particle
residue

Things to do

4.8 Make some "instant" coffee by first crushing some coffee beans, boiling them in water, filtering the mixture and finally evaporating the filtrate to dryness on a clock glass. You can use your instant coffee to make a quick cup of coffee. Does it have the same flavour as coffee made by adding boiling water to crushed coffee beans? Explain your answer.

4.9 How would you separate a mixture of soil and iron filings?

4.10 Prepare a sample of eucalyptus oil. Chop up some eucalyptus leaves, mix them with water and distil the mixture, using the apparatus shown in figure 4.7.

4.11 Chromatography is used for separating small quantities of mixtures of dyes that are soluble in water. Blue ink is such a mixture. Place a drop of ink about 5 cm from the end of a strip of clean blotting paper. Allow the ink to dry and stand this end of the blotting paper in about 1 cm of water in a beaker. Water rises in the paper and carries the different substances in the mixture to different heights.

4.12 Are you interested in car engines? Find out where the filters are fitted in the engine. Examine them when they are being replaced.

4.13 Find out how a mechanical pea harvester picks the peas and extracts them from the pods.

4.14 Make a list of tools and utensils used for separating things at home. For example, a rake can be used for separating large lumps from a garden bed. What does a tea strainer do? Make a list explaining what each utensil separates.

4.15 Smoke from factories and power stations causes pollution. Industry is required by law to reduce this pollution. Try to find out how particles are extracted from smoke before it comes out of the chimney.

4.16 Suppose that some water is accidently added to a bottle containing kerosene. Suggest a method for separating the kerosene from the water. Has your school a separating funnel?

4.17 Make a list of the methods that could be used to obtain clear water from muddy water. Can you suggest four?

4.18 After much use, the cleaning fluid in a dry-cleaning workshop becomes contaminated with dust, oil and grease. Suggest a way the cleaning fluid could be purified.

4.19 Have you any filters inside your body? Is there any filtering done by your nose, lungs, heart, blood, kidneys, and so on? Refer to your library and write a short paragraph about each of these filters.

Test yourself (chapter 4)

1. Name the pieces of apparatus labelled (a) to (k) in figures 4.9 and 4.10. Write the answers in your workbook.

In answering questions 2 to 6, choose the best answer to each question and write its letter in your workbook:

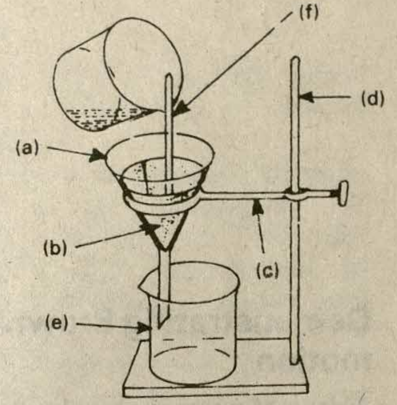


Figure 4.9

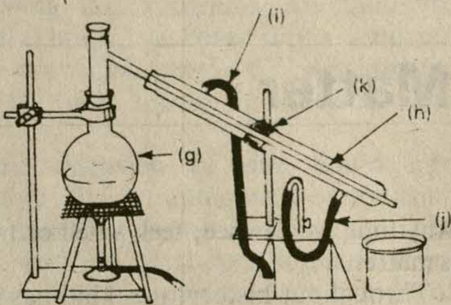


Figure 4.10

2. A vacuum cleaner collects the dust from the carpet in a current of air. This dust is removed by:
   (a) centrifuging
   (b) distillation
   (c) filtration
   (d) evaporation.
3. Salt is commercially separated from sea water by:
   (a) evaporation
   (b) filtration
   (c) distillation
   (d) centrifuging.
4. A small spot of grease on a dress may be removed by rubbing with a cloth soaked in petrol. The grease is removed by:
   (a) evaporation
   (b) filtration
   (c) solution
   (d) gravity separation.
5. The apparatus in figure 4.8 could be used to obtain:
   (a) pure water from sea water
   (b) sand from a mixture of sand and salt
   (c) sand from a mixture of sand and soil
   (d) salt from a mixture of salt and sugar.
6. The apparatus in figure 4.5 can be used to obtain:
   (a) alcohol from a mixture of alcohol and water
   (b) sand from a mixture of sand and salt
   (c) sugar from a mixture of sugar and salt
   (d) cream from milk.

5

Matter

Anything we can see, feel, smell or taste is matter.

Throughout history, mankind has not only noticed things happening, but has also tried to give satisfying explanations of these happenings. Such explanations are called theories. Primitive people explained storms by saying their gods were angry. Such a theory is not acceptable to modern people because a theory, to be really useful, must be able to predict future happenings as well as explain past happenings.

In this chapter we are going to use a theory to explain some of the things that can happen to matter. This theory is called the *particle theory of matter.*

The particle theory of matter

In 1829, a Scottish botanist called Brown noticed tiny pollen grains in water moving around in a completely disordered fashion. It took fifty years for scientists to agree on a theory to explain this. This theory stated that the pollen grains in this experiment danced around because they were being struck violently by moving particles of water.

On a sunny day a shaft of sunlight lights up the tiny dust particles in the air. These particles have the same erratic motion that Brown observed in 1829. This behaviour is known as *Brownian motion*.

Demonstrating Brownian motion

A drop of water is placed on a glass slide and a faint smear of PVA glue is added. The drop is covered with a glass slip and examined under the high-power objective of a microscope. The particles of glue can be seen moving around in a jerky fashion. They are being struck by moving particles of water. This is a demonstration of Brownian motion. (See figure 5.1.)

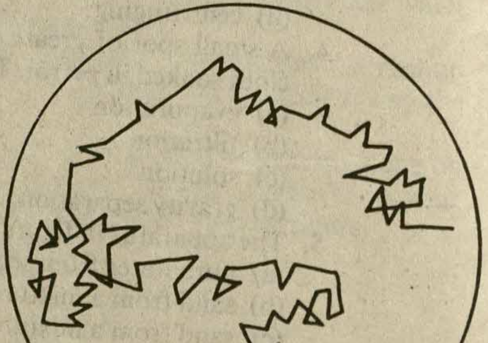


Figure 5.1: Brownian motion. This is a drawing of a long-exposure photograph of the track of a single smoke particle, as seen through an ultramicroscope examining smoke particles in air.

Diffusion

The way in which a gas will spread throughout a room may be demonstrated as follows:

A bottle of strong scent is placed on the bench of the laboratory. The students are asked to close their eyes. The stopper is then removed from the bottle and the students are asked to raise their hands and open their eyes when they first smell the perfume. In this way the class can see the rate at which the perfume spreads throughout the room.

The spreading of one substance into another is called diffusion. It is the movement of the particles of the perfume that makes it spread through the air.

Figure 5.2 demonstrates a further example of the diffusion of a gas. The brown gas is prepared by pouring nitric acid onto copper in the bottom jar. After allowing the apparatus to stand for several hours, the cover slip is removed. The brown gas slowly diffuses into the top jar, even though it is heavier than air.

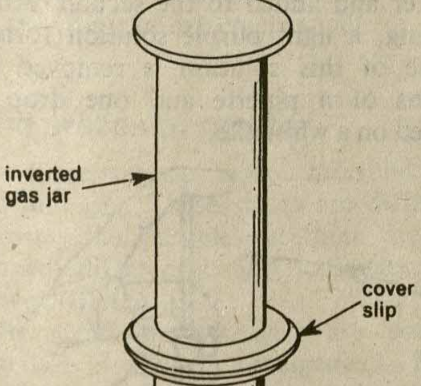


Figure 5.2: Diffusion of gases. Diffusion of the brown gas (nitrogen dioxide) into the upper gas jar occurs when the cover slip is removed.

The diffusion of one liquid into another may be demonstrated by using the apparatus shown in figure 5.3. The blue solution of copper sulphate is introduced to the bottom of the cylinder of water by carefully pouring it into the thistle funnel. The cylinder is stored in a

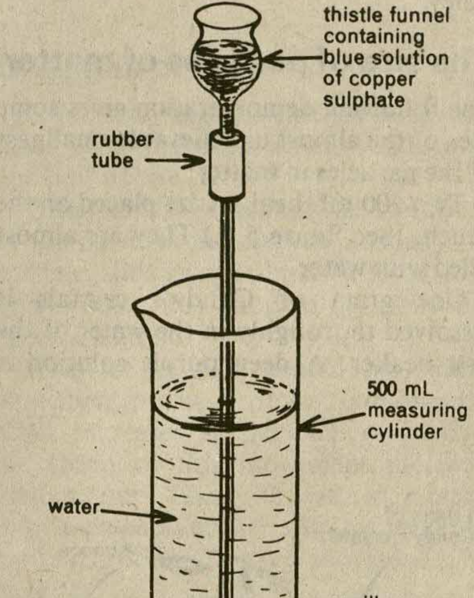

thistle funnel containing blue solution of copper sulphate
rubber tube
500 mL measuring cylinder
water
capillary tube
blue solution of copper sulphate

Figure 5.3: Diffusion of liquids. Placing a layer of coloured solution at the bottom of a column of water in a measuring cylinder, for a diffusion experiment.

quiet cool place away from sunlight and inspected daily over a period of two to three weeks. It will be noticed that the blue colour diffuses very slowly upwards. This demonstrates the fact that liquids diffuse much more slowly than gases.

Solids do not diffuse at all when placed in contact with one another. The layers of sandstone shown in figure 5.4 have been pressing against one another for over 100 million years. They are still quite separate. There has been no noticeable diffusion of one layer into the other.

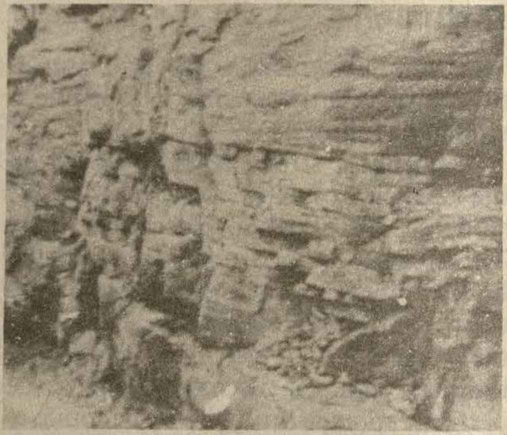


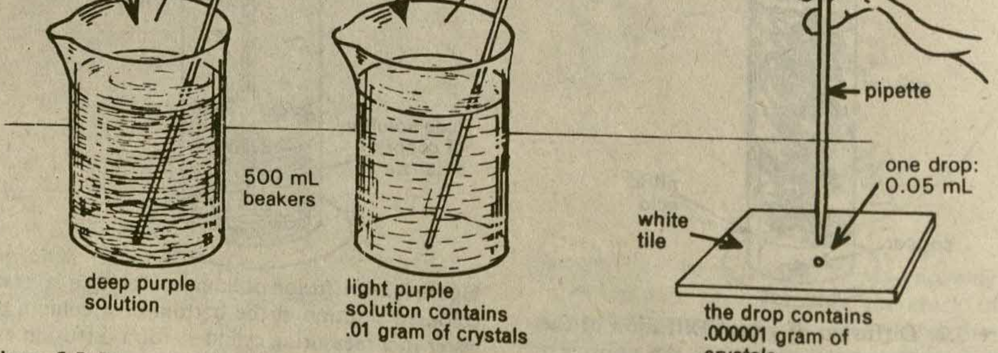
Figure 5.4: A road cutting in Hawkesbury sandstone. The layers are quite separate even though they have been pressing against one another for millions of years. Solids do not diffuse.

The size of particles of matter

The following demonstration gives some idea of the almost unbelievable smallness of the particles in matter:

Two 500 mL beakers are placed on the bench. (See figure 5.5.) They are almost filled with water.

One gram of Condy's crystals is dissolved thoroughly in the water of the first beaker. A deep purple solution is formed. A medicinal teaspoonful (5 mL) of this solution is taken from the first beaker and added to the second. After stirring, a light purple solution forms. Some of this solution is removed by means of a pipette and one drop is placed on a white tile.



1 gram of Condy's crystals
5 mL medicinal spoon
stirrer
500 mL beakers
deep purple solution
light purple solution contains .01 gram of crystals
pipette
one drop: 0.05 mL
white tile
the drop contains .000001 gram of crystals

Figure 5.5: Demonstrating the smallness of particles of matter.

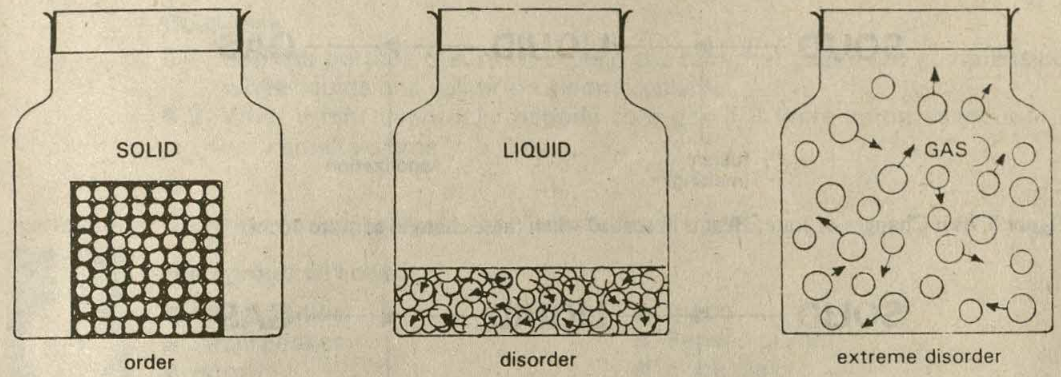


Figure 5.6: The three states of matter. In each state the tiny particles are in constant motion. In solids each particle vibrates around a fixed position; in liquids particles slide over one another; in gases particles move in straight lines until colliding with other particles or the walls of the container. (The particles are shown here much larger than their actual size.)

It can be shown that the weight of Condy's crystals in this drop is only 0.000001 gram or one-millionth of a gram. The particles of Condy's crystals are spread throughout the drop, so it can be seen that a single particle of the crystals must be extremely small.

The states of matter

The three states of matter are solid, liquid and gas. These states are different because the particles in them are arranged differently and because they move differently.

In *solids* the particles are packed together in a fixed arrangement. Each particle remains close to the same neighbours, while vibrating about a central position.

In *liquids* the particles are about as closely packed as in solids, but they slide over each other in all directions.

In *gases* the particles are more widely separated and have much more freedom to move. Each particle travels in a straight line until it collides with another particle or the walls of the vessel that contains the gas.

Changes of state

The particle theory helps us to understand what happens when solids melt and liquids boil.

When a solid is heated the vibrations of the particles increase until finally the particles slide away from their fixed positions. When this happens the solid has become a liquid.

When a liquid is heated the sliding movement of the particles, one over the other, increases. As the temperature rises the speed of this movement increases further, until finally the particles break free from one another. At this stage the liquid has become a gas. (See figure 5.7a, page 46.)

The *melting point* of a solid substance is the constant temperature at which this substance fuses (melts) and so becomes a liquid.

The *boiling point* of a liquid substance is the constant temperature at which this substance boils and so becomes a gas.

The gaseous state is the most energetic state of matter. If a gas loses heat to its surroundings it may change back to the liquid state. This change is called condensation. When a liquid loses heat it

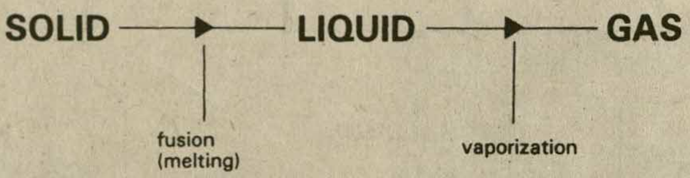


Figure 5.7(a): Changes of state. Heat is absorbed when these changes of state occur.

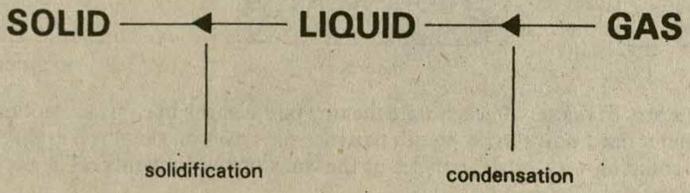


Figure 5.7(b): Changes of state. Heat is given out when these changes of state occur.

may change back to a solid. This change is called solidification. (See figure 5.7b.) The solid state is the least energetic state of matter.

Thermal expansion

Most things expand when heated. The particle theory can be used to provide an explanation for this effect. Take gases as an example. A temperature rise causes faster movement of the particles. This causes them to collide more violently so that they bounce off to greater distances from one another. Thus the gas occupies a greater space.

A temperature rise in solids and liquids also causes greater movement of the particles. Again the particles collide more violently and more space is thus taken up.

Compressing matter

An ordinary bicycle pump or syringe may be used to show that air can be compressed. A finger is placed firmly over the opening to prevent air coming out. You will find you can still push the piston down a considerable distance, thus making the volume of air in the pump smaller. This compression can be explained by the particle theory — the air particles have been pushed closer together. Why is the pressure greater? (You can tell this because it becomes harder to push the piston down any further.) It is because the particles bombard the piston more frequently.

Now fill the pump with water by placing the end in a beaker of water and pulling the piston upwards. Again block the opening with your finger. You will find that it is impossible to move the piston downwards as was possible with air. The water is incompressible.

Different gases such as town gas and Porta-gas may be tested, as well as liquids such as methylated spirits and kerosene. All these experiments will show that gases are compressible and liquids are incompressible.

Multistorey buildings are made of materials such as concrete, steel and bricks. The weight of the building on the bottom storey is tremendous, but no noticeable compression takes place. Solids, like liquids, are incompressible.

Questions

5.1 Use the particle theory to explain the fact that gases are compressible while liquids and solids are incompressible.

5.2 What might eventually happen to a gas if it were compressed into a very small volume?

EXPERIMENT

5.1

Using ice to demonstrate the three forms of matter

Each group will need:

- six ice cubes
- small beaker
- gauze
- tripod
- Bunsen burner
- clock glass

What to do

- Place the ice cubes in the beaker on the gauze and heat gently with the Bunsen burner.
- Continue heating until the water formed from the ice boils.
- Hold a cold clock glass above the beaker.

Questions

5.3 (a) What form of matter is ice?
(b) What form does it change into when it is heated?

5.4 (a) What form of matter does water change into when it boils?
(b) Can you see steam?
(c) What form of matter is the white cloud above the beaker? How do you know?
(d) What formed on the cold clock glass above the beaker?

EXPERIMENT

5.2

At what temperature does liquid naphthalene change to solid naphthalene?

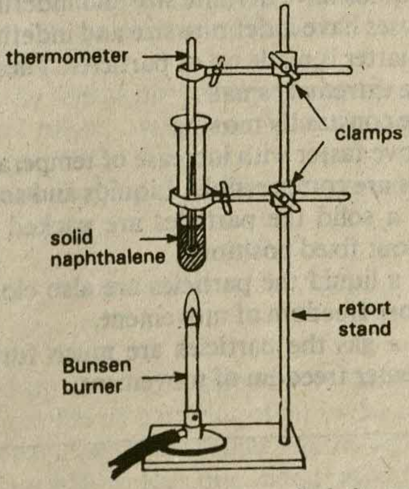


Figure 5.8: The beginning of an experiment to find the temperature at which liquid naphthalene changes into a solid.

Each group will need:

- test tube
- retort stand
- two clamps and boss-heads
- naphthalene
- one 100 °C thermometer
- Bunsen burner

What to do

- Fill the test tube to about one third with solid naphthalene.
- Clamp the test tube and thermometer to the retort stand, as shown in figure 5.8.
- Heat the naphthalene very gently by waving the burner backwards and forwards beneath the test tube.
- When all the naphthalene has melted, remove the burner and record the temperature of the naphthalene to the nearest degree.
- Read the temperature every half minute until all the molten naphthalene has solidified. Tabulate your results as follows:

Time (minutes)	0	½	1	1½	
Temp. (°C)					

Question

5.5 Did the temperature of the molten naphthalene fall at a steady rate? If it did not, was there a temperature around which it fell more slowly? Can you suggest what was happening at this temperature?

Matter

1. Matter can exist as solid, liquid or gas.
    - Solids have definite size and definite shape.
    - Liquids have definite size and indefinite shape.
    - Gases have indefinite size and indefinite shape.
2. All matter is made up of particles. These particles:
    - are extremely small
    - are constantly moving
    - move faster with increase of temperature.
3. Gases are compressible. Liquids and solids are incompressible.
4. - In a solid the particles are packed close together and vibrate about fixed positions.
    - In a liquid the particles are also close together but have much more freedom of movement.
    - In a gas the particles are much further apart and have much greater freedom of movement.

Spelling list

bicycle
compressible
concrete
condensation
diffusion
fuse
incompressible
microscope
naphthalene
particle
pollen
syringe
theory
vaporization
vapour
vibrate

Things to do

5.6 Inflate a small balloon and tie the neck to seal it. Place the balloon under a sealed bell jar connected to a vacuum pump. What happens to the balloon as air is pumped out of the bell jar?

5.7 Which gas diffuses faster — ammonia or hydrochloric acid gas? Hold the ammonia bottle near the concentrated hydrochloric acid bottle with the stoppers removed. What happens? Moisten a rubber stopper with ammonia and a second stopper with hydrochloric acid. Immediately afterwards fit the stoppers into the opposite ends of a glass tube. Where does the white cloud form? Which gas spreads faster along the tube?

5.8 Do all liquids change to a gas at the same rate? Take three pieces of rag. Soak one in water, another in methylated spirits and the third in ether (take care: ether is highly flammable). Hang the wet rags over a rod. Did all the rags become dry at the same time? If not, which dried first and which last?

More questions

5.9 Some people explain events by the stars. They also predict the future by the stars. What do you think of the theory that the stars affect the lives of individuals?

5.10 Which of the following would you consider to be forms of matter: a crystal of sugar, town gas, noise, an elastic band, a push, a nail, electricity, butter?

5.11 Name a solid (one for each case) that you can recognize by your sense of
(a) touch
(b) taste
(c) sight
(d) smell.

5.12 A pumped-up car tyre is allowed to stand in the sun on a hot day. Does the number of particles of air in the tyre change as the tyre gets hotter? What change takes place in the movement of the particles of air in the tyre? How does this change affect the air pressure inside the tyre?

Test yourself (chapter 5)

1. Copy and complete the following table in your workbook, using the substances listed below.

water
petrol
margarine
solder
soap
oxygen
sugar
icecream

Solid at room temperature (a)	Liquid at room temperature (b)	Gas at room temperature (c)

2. Complete the following sentences in your workbook:
   (a) When a liquid changes to a gas, it is said to ____________.
   (b) When a gas changes to a liquid, it is said to ____________.
   (c) When a liquid changes to a solid, it is said to ____________.
   (d) When a solid changes to a liquid, it is said to ____________.

In questions 3 to 5 choose the best answer to each question and write its letter in your workbook.

3. Gases are more easily compressed than liquids and solids. This is because the particles of a gas compared to the particles of liquids and solids are:
   (a) further apart
   (b) smaller
   (c) not moving as rapidly
   (d) closer together.
4. When a solid melts, its particles:
   (a) become smaller
   (b) move more freely
   (c) become lighter
   (d) become transparent.
5. The fact that gases expand when heated can be explained by saying that the particles:
   (a) become bigger
   (b) move faster
   (c) become lighter
   (d) become smaller.

6

Elements and compounds

Chemistry is the science that deals with the composition of substances. When a chemist attempts to find out what table salt is made of, he is said to be *analysing* it. A chemist could also be asked to use a number of substances to make a new substance. This process, the opposite of analysis, is called *synthesis*. Nylon, for example, is called a synthetic because it is made by combining simpler substances.

Early people investigated matter. They extracted and used gold, tin, copper, iron and charcoal. They fashioned bricks from clay and glass from sand. Their building materials were mainly wood and stone. But they were more concerned with the use of all these substances than with their composition.

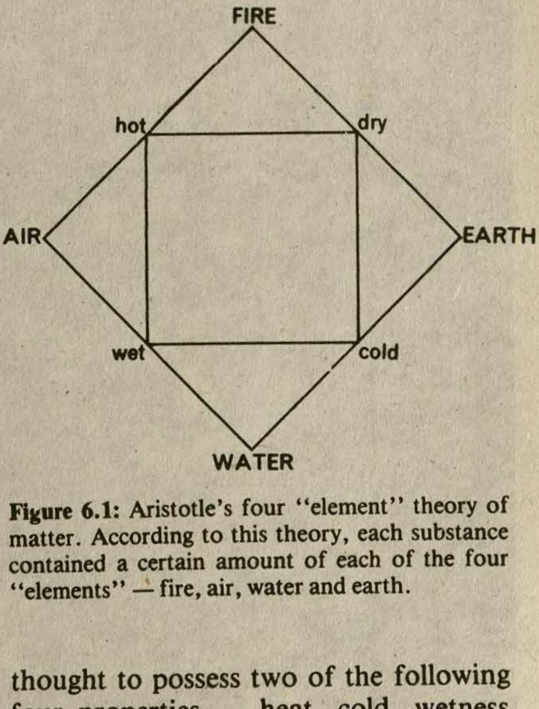


Figure 6.1: Aristotle's four "element" theory of matter. According to this theory, each substance contained a certain amount of each of the four "elements" — fire, air, water and earth.

Elements

Aristotle, a famous Greek philosopher of the fourth century B.C., was one of the first to suggest a system of analysing substances. Aristotle only discussed ideas — he did no experiments or tests to see if his ideas were right.

His idea, or theory, on the subject of analysis was that all known substances were made up of different amounts of four "elements" — fire, air, water and earth. Each of these "elements" was thought to possess two of the following four properties — heat, cold, wetness and dryness. (See figure 6.1.)

Take the burning of wood as an example. In Aristotle's days people would have said wood burns to form fire, air, water and earth. In comparison, today we would say that wood burns to form heat, gases, liquids and ash.

Aristotle's theory was accepted for 2000 years. It was the theory of the alchemists, those men of the Middle

Figure 6.2: A painting by the Englishman Joseph Wright showing the German alchemist Hennig Brand discovering the new element phosphorus in 1669. (Reproduced by permission of the Derby Art Gallery)

Ages whose efforts were directed mainly towards changing base metals into noble metals such as gold. Although unscientific by today's standards, the alchemists built up a store of knowledge about many substances. They also developed such processes as distillation, crystallization, smelting and alloying. They probably isolated the true elements phosphorus, arsenic, antimony, bismuth and zinc, while still believing in Aristotle's fire, air, water and earth theory.

A new attitude

About the middle of the seventeenth century a new attitude began to develop among those working on the nature of substances. People began to question theories that could not be proved. They refused to believe, for example, that earth, air, water and fire could be united to form wood unless they saw someone actually do it. This was the birth of a new approach to investigations and a new theory about elements.

The modern theory of elements

Modern chemistry began when the four-"element" theory was questioned and replaced.

In 1661 Robert Boyle presented a principle that was accepted and is today the basis of chemistry. Boyle's principle stated that some substances are simple and cannot be split up into simpler substances, and that other substances are compounded from these simple substances. The former are now called *elements* and the latter *compounds*. By the beginning of the nineteenth century the following substances had been prepared and classified as elements:

Metals	Non-metals
antimony	arsenic
bismuth	carbon
cobalt	chlorine
copper	hydrogen
gold	iodine
iron	oxygen
lead	nitrogen
manganese	phosphorus
mercury	sulphur
nickel	
silver	
tin	
zinc	

Today all the naturally occurring elements that exist on earth have been isolated. There are ninety-two in all, ranging from hydrogen (the lightest) through to uranium (the heaviest). Scientists have gone even further and made more elements by artificial means in atomic reactors. One of these elements is plutonium.

Physical and chemical changes

Everywhere around us we see materials changing. Water evaporates off the road after a shower of rain. Steam from the kettle condenses to form a cloud of tiny drops of water. Water freezes into ice cubes in the refrigerator. Iron tools left out in the weather become rusty. Meat overcooked in the oven turns into charcoal. Plants grow, die and decay. Wood burns and ash is left. Food we eat is changed into flesh and bone, among other things.

Sometimes these changes result in the formation of completely new substances. At other times the change produces no new substance at all.

Physical change

The freezing of water to form ice is a physical change. No new substance is formed; there is merely a change of state. During this change heat is given out and it is quite easy to recover the water by supplying heat to melt the ice.

For the same reason, the boiling of water to change it into steam is a physical change.

No new substance is formed when a glass bottle is dropped and shattered. Provided you had the necessary machinery you could melt the glass pieces and mould them back into the shape of the bottle again.

When an electric light bulb is switched on, the filament becomes white hot. The same filament is in the bulb when the current is switched off, but it is cold and does not glow.

Chemical change

A good example of a chemical change is the burning of magnesium. If a strip of the metal is held in a flame with a pair of tongs it catches alight and burns with a dazzling white flame. (See figure 6.3.) Avoid looking directly at this flame because it might damage your eyes. After burning ceases, you will find that the magnesium has changed into a white powder.

During this change (from magnesium to the white powder) a lot of heat and light is given out, and once the white powder is formed it is very difficult to change it back into magnesium.

In a chemical change:

- A new substance is always formed.
- The change is usually difficult to reverse.
- Energy, generally in the form of heat, is either given out or absorbed.

When sugar is heated in a test tube, it

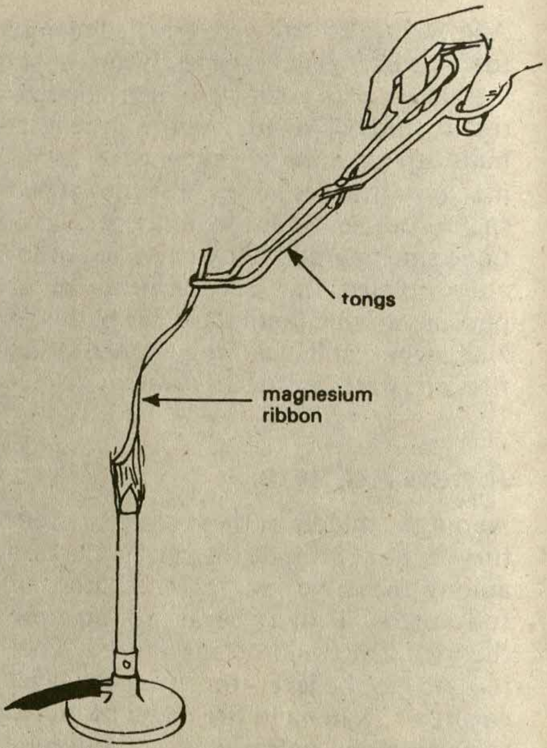


Figure 6.3: Heating some magnesium ribbon until it catches alight. Do not look directly at the burning magnesium, as the brightness of the flame may damage your eyes.

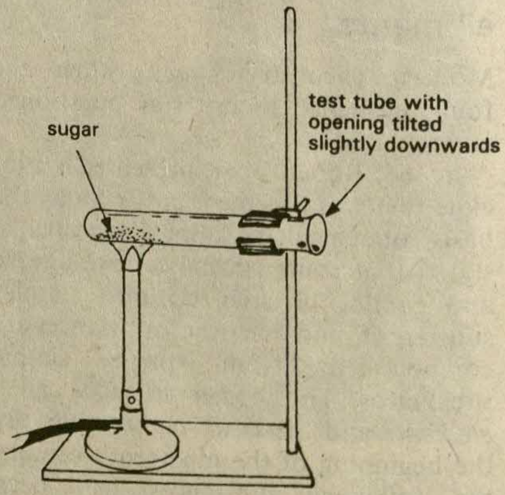


Figure 6.4: Heating sugar crystals in a test tube.

chars and forms charcoal and steam. (See figure 6.4.) It is obvious that charcoal is very different from sugar, and it is very difficult to turn charcoal back into sugar. The charring of sugar is another example of a chemical change.

Further chemical changes are carried out in experiments 6.1, 6.2 and 6.3.

Compounds

Copper and chlorine are both elements, that is, pure simple substances. Chlorine is a green gas. A piece of copper wire is heated in a Bunsen flame and held in a jar of chlorine, as shown in figure 6.5. The copper becomes red hot and burns to form brown smoke. The copper and chlorine have combined to form a compound of the two elements.

copper + chlorine ⟶ copper chloride

A chemical change is also called a *reaction*. In this case, we say that copper and chlorine have reacted together.

Notice that the name of the compound is copper chloride and not copper chlorine. Copper chloride is a single substance. Copper and chlorine are two *simple* substances.

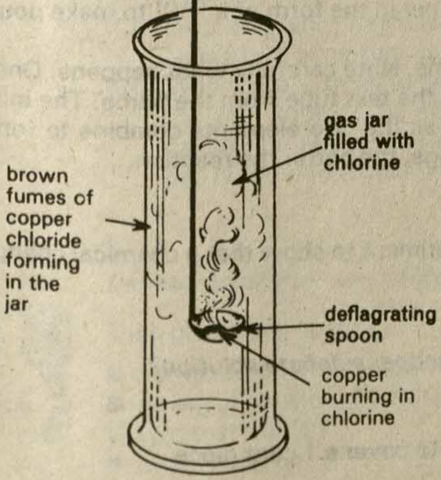

gas jar filled with chlorine
brown fumes of copper chloride forming in the jar
deflagrating spoon
copper burning in chlorine

Figure 6.5: A piece of hot copper wire catches fire in chlorine. The copper burns in the chlorine to form copper chloride.

A chloride is a compound of two elements, one of which is chlorine. The commonest chloride is table salt (sodium chloride). One way of making table salt, therefore, is to burn the metal sodium in chlorine.

Aluminium powder and sulphur also combine when heated, to form the compound aluminium sulphide. The experiment is carried out by heating a mixture of approximately equal parts of the two elements in a test tube held in a clamp stand. (See figure 6.6.) Do not hold the test tube in your hand because a tremendous amount of heat is given out.

The formation of aluminium sulphide is an excellent example of a chemical

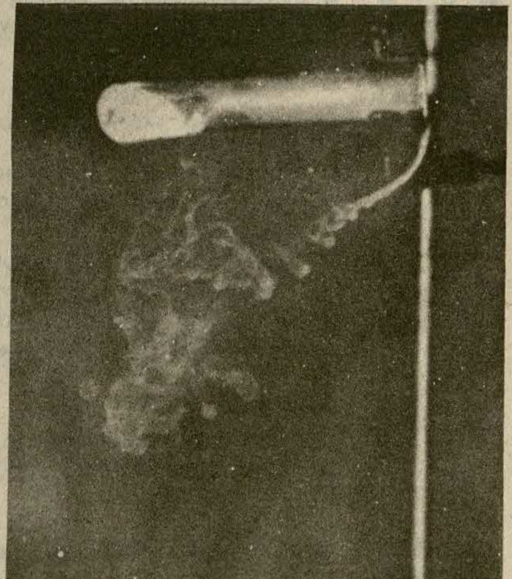


Figure 6.6: A mixture of aluminium powder and sulphur combining to form aluminium sulphide. Note that the test tube is white-hot.

change. To show that a completely new substance is formed, put a little water on the contents of the test tube when cool. A smell of rotten egg gas, hydrogen sulphide, is quickly noticed. Water has no effect on either sulphur or aluminium — it reacts only with a compound of the two.

Indestructibility of matter

The idea that matter is indestructible may be demonstrated with a camera flashbulb. The bulb is weighed on an electric balance or counterpoised with sand on a beam balance, then flashed by using a camera or by connecting the two contacts either side of the base to a 6-volt battery. When the spent bulb is placed back on the balance, it can be seen that there is no change in weight. Although a chemical change has occurred (this is shown by the flash of light), no new matter has been created, nor has any been destroyed.

EXPERIMENT

6.1

Making the compound iron sulphide

Each group will need:

- test tube
- powdered sulphur (enough to cover a 2 cent coin)
- an equal heap of finely powdered iron (the finer the better)
- Bunsen burner
- test tube holder

What to do

- Mix the two elements, iron and sulphur, on a piece of paper. Add the mixture to the test tube, folding the paper in the form of a "V" to make pouring easier.
- Heat the test tube in the burner flame. Note carefully what happens. Once the mixture starts to glow, remove the test tube from the flame. The mixture should generate its own heat as the two elements combine to form iron sulphide. The finer the iron filings, the better the reaction.

Question

6.1 Is there any evidence in this experiment to show that a chemical change has occurred?

EXPERIMENT

6.2

What happens when iron is added to copper sulphate solution?

Each group will need:

- enough powdered copper sulphate to cover a 1 cent piece
- test tube
- clean iron nail
- test tube stand

What to do

- Half fill the test tube with water. Add the copper sulphate and shake to dissolve.
- Slide the iron nail to the bottom of the test tube.
- Place the test tube in a stand. Observe what happens over a period of five minutes. Feel the test tube to detect any change in temperature.

Questions

6.2 Did you see any change? Did you feel any change?

6.3 Would you agree that the following statement helps to explain what happened?

copper sulphate + iron ⟶ copper + iron sulphate

6.4 What is the evidence that a chemical change has occurred?

EXPERIMENT

6.3

What happens when a piece of magnesium ribbon is added to dilute hydrochloric acid?

Each group will need:

- test tube
- about 3 cm of magnesium ribbon
- dilute hydrochloric acid
- test tube stand
- taper
- Bunsen burner

What to do

- Pour about 2 cm of the acid into the test tube set in a stand.
- Drop the magnesium into the acid.
- Light the taper and hold it near the mouth of the test tube.
- Feel the bottom of the test tube to detect any change in temperature.

Questions

6.5 Describe what happened when you added the magnesium to the acid. Name two occurrences that indicate that a chemical change took place.

6.6 Was there a small explosion when the taper was held at the mouth of the test tube? (The effervescence in the liquid in the test tube was caused by bubbles of hydrogen gas. Hydrogen burns when lit. If this gas is allowed to mix with air before it is lit, it explodes.)

EXPERIMENT

6.4

Demonstrating the law of indestructibility of matter

Each group will need:

- sufficient powdered lead nitrate to cover a 1 cent piece
- an equal heap of potassium iodide
- two test tubes
- beam balance
- sand
- beaker
- rag

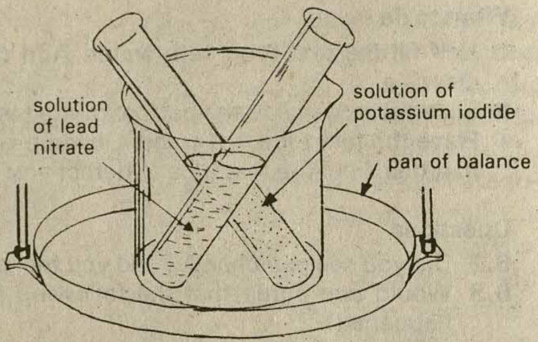


Figure 6.7: Demonstrating the law of indestructibility of matter. Weighing the two solutions before mixing.

What to do

- One third fill each test tube with water.
- Add the lead nitrate to one test tube and the potassium iodide to the other.
- Shake to dissolve. When the crystals are dissolved, dry the outside of each test tube with a rag.
- Place the test tubes in a dry beaker, as in figure 6.7. Counterpoise on a beam balance with sand.
- Carefully pour the contents of one of the test tubes into the other. Make sure nothing is spilled. Replace the test tubes in the beaker and the beaker back on the balance.

Questions

6.7 What change did you see?
6.8 Was there any change in weight?

Elements and compounds

1. Elements are pure simple substances.
2. In a chemical change:
   - a new substance is always formed
   - the change is usually difficult to reverse
   - heat is either given out or taken in.
3. A compound:
   - is a pure substance
   - contains two or more elements combined
   - cannot be separated into its elements by mechanical means such as filtering, centrifuging, and so on.
4. The Law of Indestructibility of Matter states that matter can be neither created nor destroyed.

Spelling list

aluminium
analyse
char
chemical
chlorine
effervescence
element
filament
indestructible
magnesium
mould
sulphur
synthesis

Things to do

6.9 Heat some potato, coal, rice and wood on a tin lid on a tripod. What do the results show?

6.10 Heat a little mercuric oxide in a test tube. Hold a glowing splint at the mouth of the test tube. What does mercuric oxide change into when heated? Is this a physical or a chemical change? *Caution:* Because mercury vapour is very poisonous, this experiment should be done in a fume cupboard.

More questions

6.11 What is meant by the term *element*? Which of the following substances are elements: oxygen, water, sugar, carbon, copper sulphate, hydrogen, common salt, iron, chlorine?

6.12 Give three examples of physical changes and describe how you would reverse these changes.

6.13 Explain the difference between a physical and a chemical change. Classify the following changes:
(a) ice melts
(b) dynamite explodes
(c) an electric lamp lights up
(d) iron rusts
(e) sugar is added to a cup of tea
(f) wood burns
(g) a leaf decays
(h) toast burns.

6.14 Describe what happens when:
(a) magnesium is added to dilute sulphuric acid
(b) an iron nail is placed in a solution of copper sulphate
(c) a mixture of aluminium powder and sulphur is heated
(d) solutions of lead nitrate and potassium iodide are mixed.
Which of these four are physical changes and which are chemical changes?

6.15 A motor car engine gets its power by burning petrol. The heat released in this chemical change causes gases to expand in the cylinders. This expansion forces the pistons to move. Give three more examples where use is made of heat released in chemical changes.

6.16 Classify the following as mixtures, elements, or compounds: air, oxygen, pure water, petrol, sugar, carbon, copper sulphate, sea water, soil, iron, iron sulphide, sulphur, lead, shaving cream, lemonade, bread, gold, tap water.

6.17 If naphthalene is heated, it melts to a liquid, and at a higher temperature boils to form a gas. If a flame is applied to this gas, it ignites and burns brightly. Which of these three changes are physical changes and which are chemical?

Test yourself (chapter 6)

Choose the best answer to questions 1 to 4, and also to question 6, and write its letter in your workbook.

1. Copper, oxygen, chlorine, sulphur, gold and iron are all:
   (a) compounds
   (b) mixtures
   (c) elements
   (d) metals.
2. Air, blood, sea water, copper sulphate, soil and iron sulphide are:
   (a) all mixtures
   (b) all compounds
   (c) examples of mixtures and compounds
   (d) examples of elements and mixtures.
3. If a mixture of iron filings and sulphur is heated and all the iron reacts with all the sulphur, the weight of the product formed is:
   (a) less than the original weight of the iron and sulphur
   (b) the same as the original weight of the iron and sulphur
   (c) more than the original weight of the iron and sulphur.
4. When two elements react together they always produce:
   (a) a sulphide
   (b) a compound
   (c) a solid
   (d) new elements.
5. Complete the following word equations in your workbook.
   (a) iron + sulphur $\xrightarrow{\text{heated}}$
   (b) lead nitrate solution + potassium iodide solution →
   (c) iron + copper sulphate solution →
   (d) sugar $\xrightarrow{\text{heated}}$
6. All of the above reactions are examples of:
   (a) analysis
   (b) synthesis
   (c) chemical change
   (d) physical change.

7

Energy

Energy is all around us; it is even in our bodies. It is not easy to say what energy is, but it is easy to understand what energy can do.

No doubt you can remember the last power failure in your district. Think of all the things that stopped working when this happened. The lights went out, the picture on the television set faded and the sound ceased. The electric stove stopped cooking the evening meal and the electric toaster stopped toasting bread. The electric motor in the food mixer stopped and the beaters ceased to rotate.

All these appliances work only when an electric current is passing through them. Electricity can make things move; it can heat things and produce light and sound. We say electricity has energy.

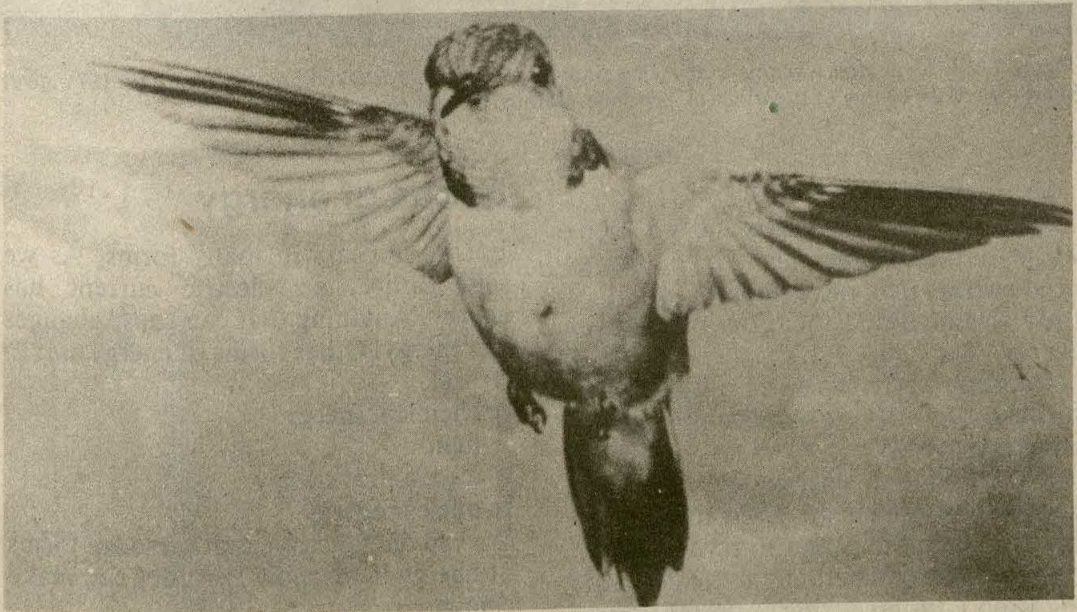


Figure 7.1: A hummingbird — the rufous flame-bearer — hovering in flight like a helicopter. Its wings beat at a rate of up to 70 times per second; to take this photo an exposure time of 1/6000 second was needed. The hummingbird, which is native to America, is a small bird, but for its size it uses more energy than any other animal. To obtain its energy it eats as much as twice its weight in food per day. (Its food is mostly nectar obtained from flowers by sucking through a tubular tongue.) The bird's tiny heart beats 500 times per minute, pumping nourishment to its muscles. (Photo courtesy American Museum of Natural History)

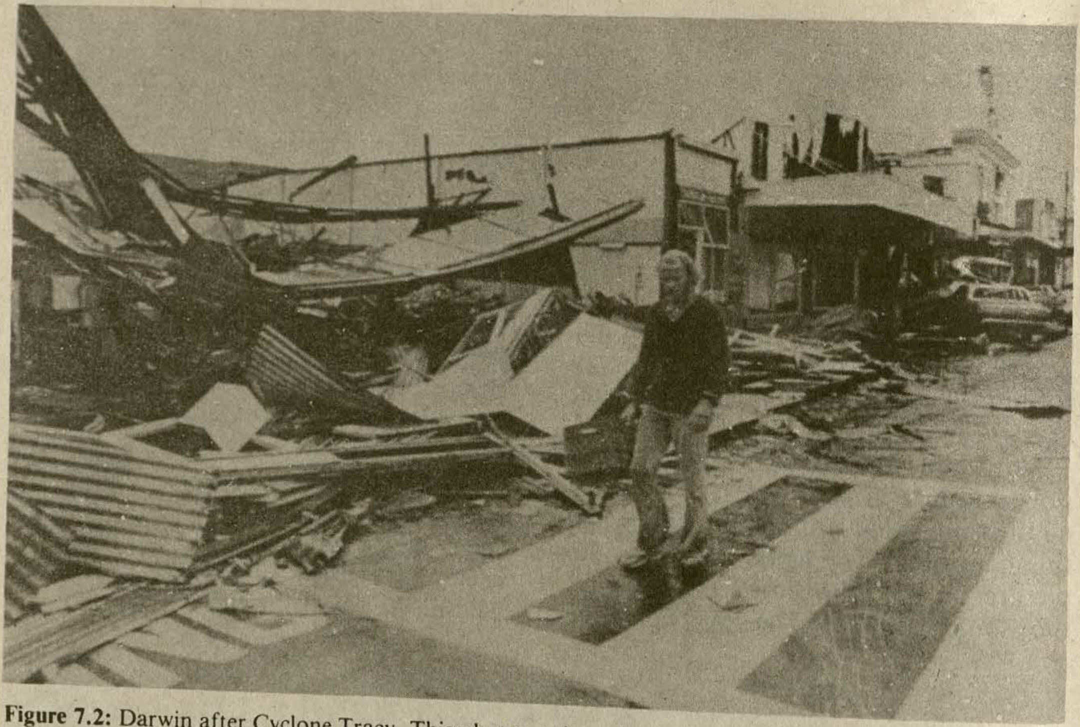


Figure 7.2: Darwin after Cyclone Tracy. This photograph, which was taken on Christmas Day 1974, gives some idea of the energy of the winds of a cyclone. (Photo courtesy News Ltd)

We ourselves can move and we keep warm during cold weather. To do this we need energy. Our energy comes from the food we eat. Food therefore must have energy. (See figure 7.1.)

Running water has energy: it can turn turbines or move rocks and pebbles along a river bed.

The wind has energy. People have been using this energy for centuries to propel sailing boats and to turn the sails of windmills. Sometimes the energy of the wind is so great that it uproots trees and unroofs houses.

Motor cars use energy as they move along. This energy comes from the petrol in the petrol tank. If the petrol tank runs dry, the car stops. It has run out of energy.

Forms of energy

Energy appears in many forms. As we said earlier, an electric current has energy. Anything that can cause changes has energy. Other forms of energy are:

- heat
- chemical energy
- light
- mechanical energy
- nuclear energy.

We can demonstrate that these are forms of energy if we show that they can make changes.

Electrical energy

What are some of the changes electrical energy can make?

Electricity can be used to lift things, as shown in figure 7.3.

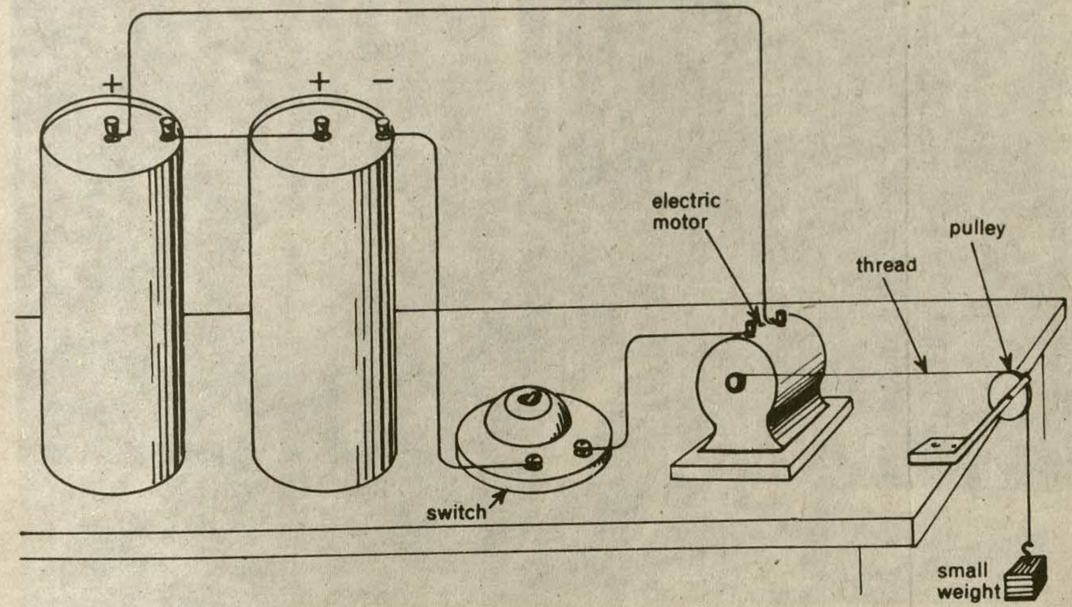


Figure 7.3: Electricity being used to lift a small weight. The electricity comes from the battery and is changed into mechanical energy by the motor.

Electricity can heat an iron wire. (See figure 7.4.)

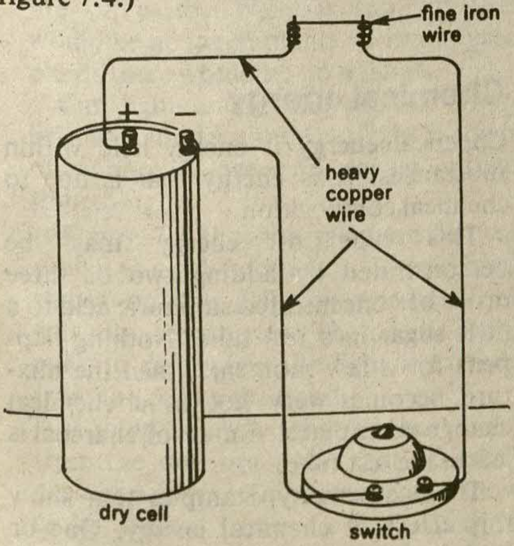


Figure 7.4: Changing electricity into heat and light. The fine iron wire gets hot and glows as the current of electricity flows through it.

Heat energy

Heat energy can be used to rotate the flywheel of a model steam engine. (See figure 7.5.) The heat energy to drive the motor comes from burning methylated spirits, which is placed beneath the boiler.

Modern societies use a tremendous amount of heat energy. For example, it is used to drive thermal power stations (the word "thermal" means heat). In these power stations the heat comes from burning coal, or sometimes from burning oil. Heat is also used in the smelting of iron ore, that is, in changing the ore to iron.

Another demonstration of a change produced by heat energy is illustrated in figure 7.6. You should rub your hands together to make sure they are warm before putting them around the flask.

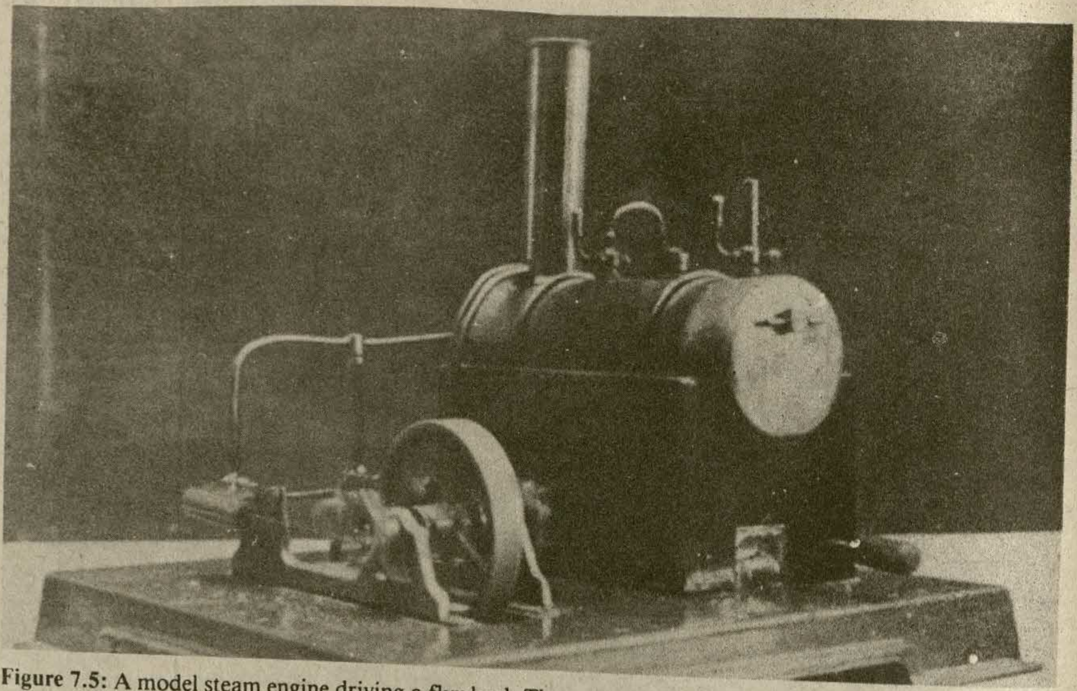


Figure 7.5: A model steam engine driving a flywheel. The energy for this is coming from methylated spirits burning under the boiler.

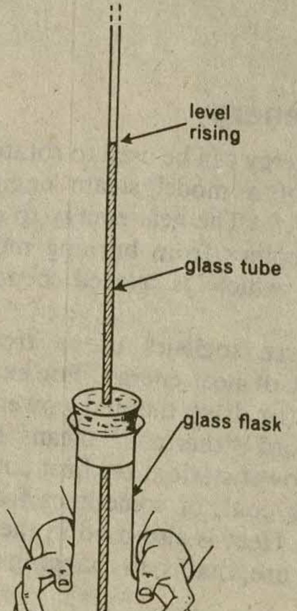


Figure 7.6: This diagram shows the rapid expansion of air when heated. Heat from the hands causes the air in the flask to expand and push the coloured water up the tube.

Heat is transferred from your hands to the air in the flask. This causes the air to expand and push down on the surface of the coloured water.

Chemical energy

Chemical energy is energy held within substances. It is energy that is due to chemical composition.

This type of energy may be demonstrated by adding two or three drops of concentrated sulphuric acid to a little sugar in a test tube. Nothing happens for a few moments, then the mixture becomes very hot as a chemical change takes place. A mass of charcoal is left in the test tube.

There are many examples that show this effect of chemical energy. One or two drops of glycerine added to a small heap of Condy's crystals on the lid of a tin releases a lot of energy. A heap of ammonium dichromate can be ignited by using a piece of magnesium ribbon as a wick.

Coal, petrol, kerosene and diesel oil all contain chemical energy, which is set free as heat when the fuel burns. You might ask if petrol actually burns inside a motor car engine. The answer is "yes"; the petrol evaporates and mixes with air as it is sucked into the engine. This gas mixture explodes when ignited by an electric spark at a spark plug. The heat energy resulting from the explosion causes gases to expand and push down a piston.

Light

Light is a form of energy. It can cause changes and make things move. A plank of wood is placed on a lawn for a week or so. When the plank is lifted we see that the grass underneath has changed from green to yellow. If the sunlight is allowed to shine on the yellow grass again, it will change back to green in a few days. The effect of sunlight on plants is of tremendous importance to all life on earth. Without sunlight there would be no green plants. Without green plants there would be no animals.

Can light make things move? It will help us to understand that light is a form of energy if we can see it moving something.

Figure 7.7 shows a selenium cell connected to a galvanometer. When sunlight shines on the cell the needle of the galvanometer moves. The needle swings back to zero when the light is excluded from the cell by the hand.

It could be argued that it is heat energy from the sun, not light, that causes the needle to move. This argument is shown to be wrong, however, by placing the warm hand down on top of the cell: the needle does not move. Therefore, light is a form of energy.

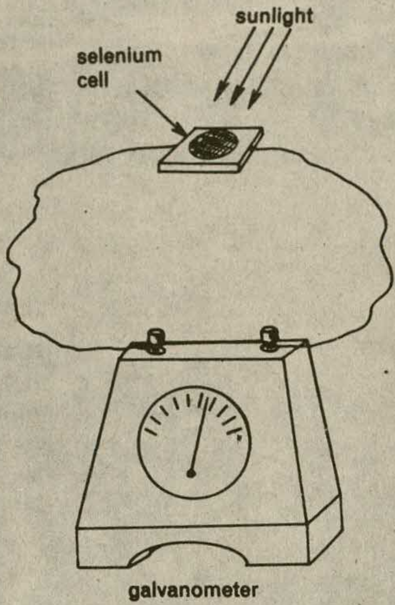


Figure 7.7: The selenium cell. A current of electricity flows through the galvanometer when light shines on the cell. Light is changed to electrical energy.

Mechanical energy

Lake Eucumbene is the biggest lake in the Snowy Mountains Hydro-electric Scheme. (See figure 7.8.) The water in the lake is still. Does it contain energy? Can it set things moving? Lake Eucumbene is 1200 metres above sea level. Three hundred metres below the lake is Tumut 1 Power Station. When the water in the lake flows down into the power station it sets the turbines moving. There is enough energy in all this stored water to keep the power station working at the rate of 300 000 kilowatts for more than a year. This type of stored energy is called *potential energy*. A wound-up clock spring contains the same sort of energy; it keeps the hands of the clock moving. Air under pressure also contains potential energy: compressed air can be used to drive jack hammers, for example.

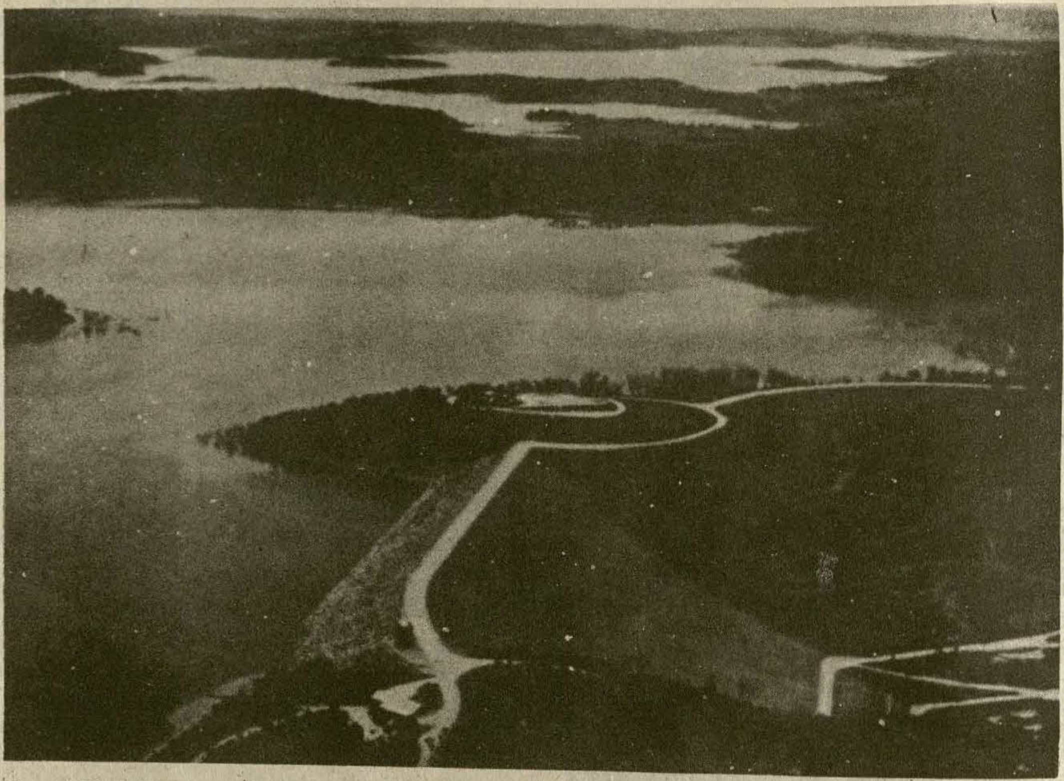


Figure 7.8: Lake Eucumbene, in the Snowy Mountains of New South Wales. When full the lake contains nine times the volume of water in Sydney Harbour. Because of its altitude it is also a huge store of energy for the power stations below it. (Photo courtesy Snowy Mountains Authority)

Another form of mechanical energy is *kinetic energy*. All moving objects possess kinetic energy. The energy of the wind is kinetic. Water flowing through pipes into a power station has the same kind of energy. It is important to remember that it is the actual motion of an object that gives it kinetic energy.

A simple pendulum illustrates the idea of potential and kinetic energy very well. We supply the energy to start it swinging by pulling the bob sideways and upwards, as shown in figure 7.9. At position A the bob is at rest but has energy because of its position; that is, it has potential energy. If the bob is released, it gathers speed until it swings through its lowest point B. At B all its energy is kinetic. It has lost its potential energy. However, as it continues to swing it loses speed as it rises to position C. In this

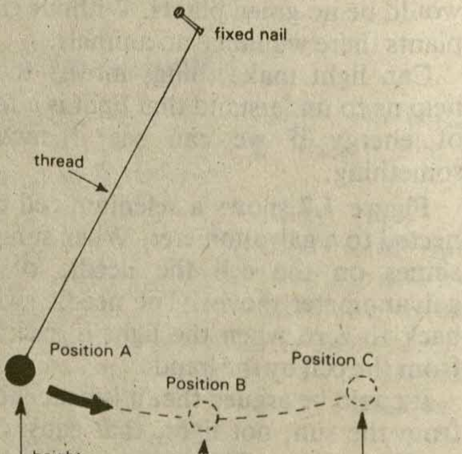


Figure 7.9: The pendulum. Its energy is changing from potential to kinetic and back to potential as it swings backwards and forwards.

position all its kinetic energy has been changed back into potential energy. As long as the bob keeps swinging, its energy changes from potential to kinetic, back to potential, and so on.

This experiment illustrates an important natural law: the law of *conservation of energy*. Energy cannot be created or destroyed. It can only be changed from one form to another.

Question

7.1 If energy cannot be destroyed, why does the pendulum eventually come to rest? Where has all the energy of the bob gone?

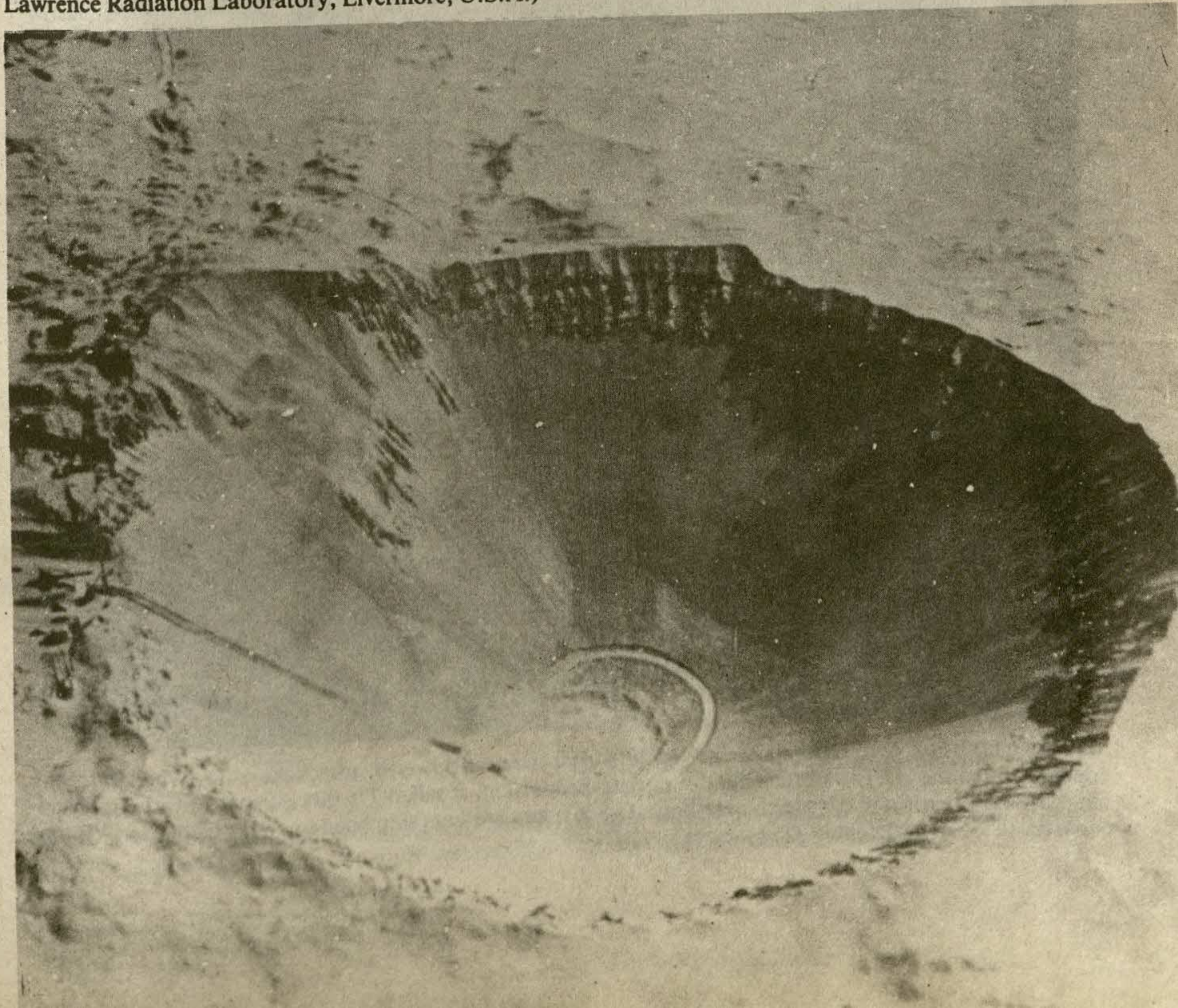
Nuclear energy

Elements are made up of very tiny particles called atoms. If the nucleus of an atom can be split, new elements are formed and a tremendous amount of energy is set free. Figure 7.10 gives some idea of the force of an uncontrolled nuclear explosion caused by the splitting of uranium atoms.

Scientists are now learning ways to control nuclear energy. Already it is being used to operate electric power stations and to drive the engines of ships and submarines. (See figure 7.11.)

Many people are concerned, however,

Figure 7.10: Operation Plowshare: excavating with an atom bomb. This huge hole was made by using only 20 kilograms of explosive material. Notice the trucks at the left-hand side of the hole. (Photo courtesy Lawrence Radiation Laboratory, Livermore, U.S.A.)



about the use of nuclear energy. They are worried that a war that used nuclear weapons could destroy us all. They also fear that the harmful radioactive wastes from nuclear power cannot be stored safely and that there could be a dreadful accident at a nuclear power station.

Solar energy

The world's petroleum supplies are rapidly being exhausted. Coal reserves will last much longer, but they too must eventually be used up. People expect that the sun will be the eventual source of much of our energy. To trap the sun's energy by means of mirrors requires a lot of mirrors, so it is very expensive. Figure 7.12 shows a plan for an experimental solar power station. It could be the power station of the future.

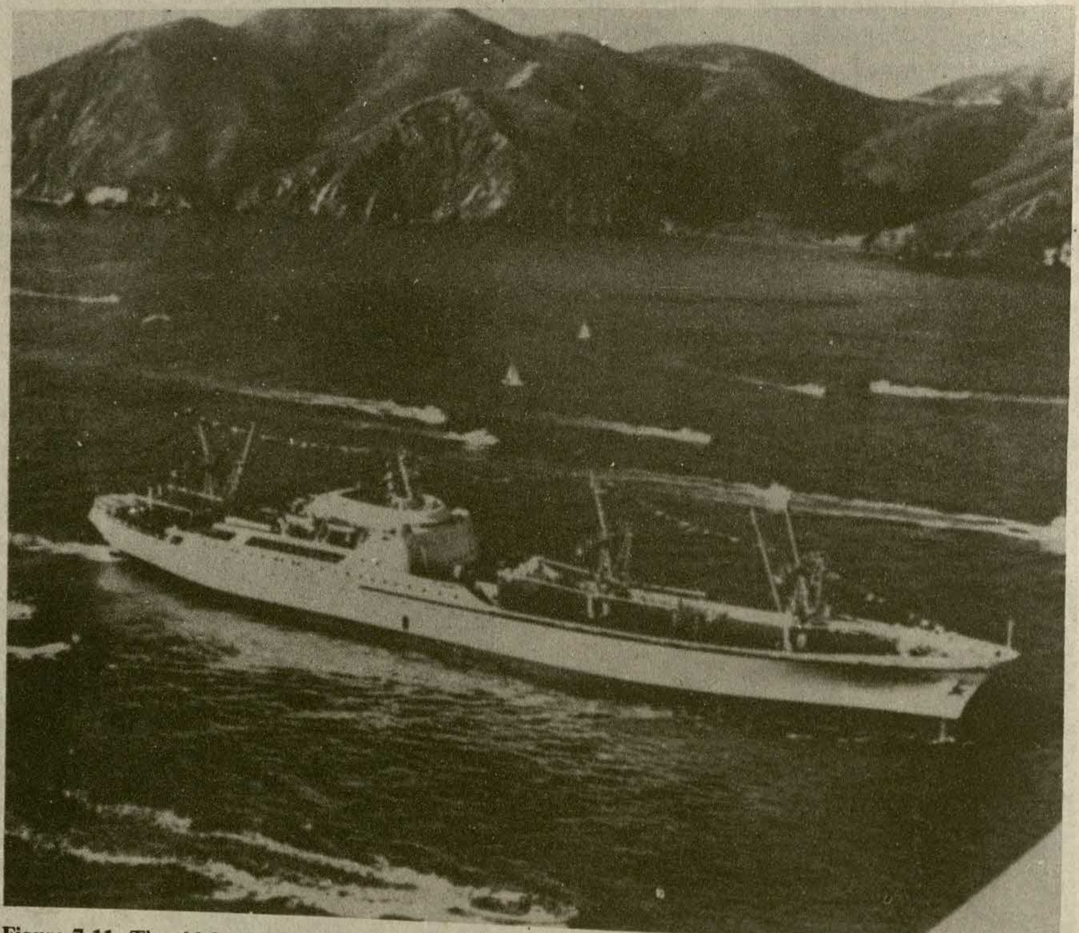


Figure 7.11: The N.S. *Savannah*, the world's first nuclear-powered merchant ship. The *Savannah* demonstrated the safety and reliability of nuclear propulsion. It sailed 775 000 kilometres without refuelling. It is now berthed in Charleston Harbour, U.S.A., as a museum ship open to public inspection. (Photo courtesy U.S. Department of Commerce)

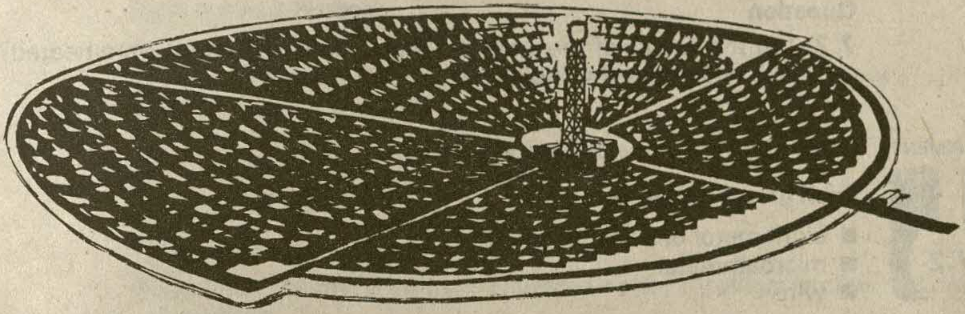


Figure 7.12: An artist's sketch of the world's first solar power station, called "Solar 1", to be built in California. Like sunflowers, the 2000 mirrors of the station will tilt to follow the sun as it moves across the sky. The heat is focused on the top of the tall tower in the centre, which contains the boiler. The station is to be in operation by 1982. Although it will have cost 123 million U.S. dollars, it will supply only enough power for a town of about 8000 people.

EXPERIMENT

7.1

Changing heat into electrical energy

Each group will need:

- microammeter
- 50 cm of iron wire
- 50 cm of copper wire
- Bunsen burner

What to do

- Twist the two pieces of wire together for about half their length, as shown in figure 7.13.
- Connect the free ends to the microammeter. Heat along the twisted section with a Bunsen burner.

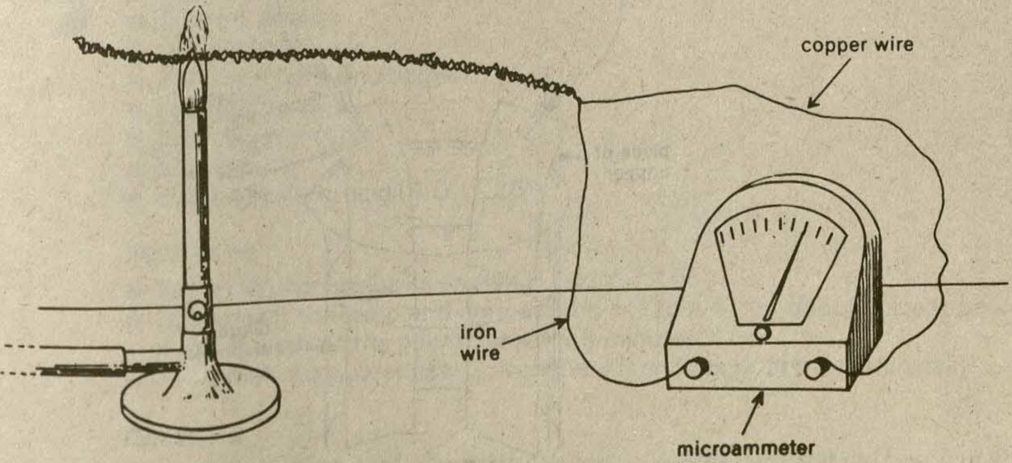


Figure 7.13: Changing heat into electricity. A small current of electricity is produced when clean pieces of copper wire and iron wire are twisted together and heated.

Question

7.2 Did the needle of the ammeter move when the wires were heated? If it did, what does this indicate?

EXPERIMENT 7.2

Changing light into electrical energy

Each group will need:

- Light meter or selenium cell
- microammeter
- wire

What to do

- Use a light meter or the apparatus shown in figure 7.7 (page 65).
- Expose the light meter to various sources of light. Observe the effect on the meter in each case.

Questions

7.3 Did the needle of the meter move? If it did, what caused it to move?

7.4 It could be argued that it is heat energy, not light energy, that caused the needle to move. Solve this problem by placing a warm hand over the selenium cell. Does this cause the needle to swing further still? What is your answer to this problem?

EXPERIMENT 7.3

Changing chemical energy into electrical energy

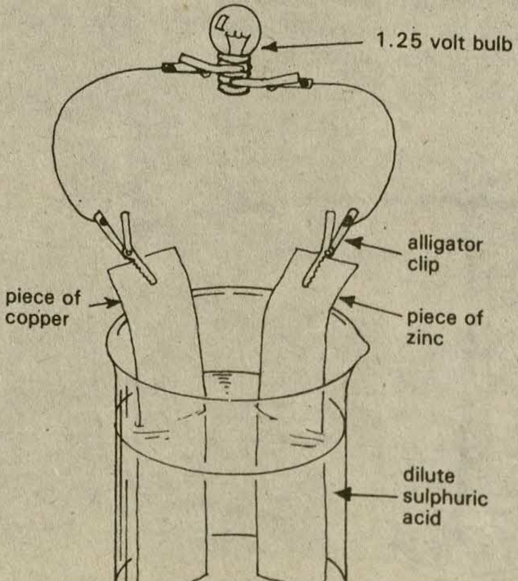


Figure 7.14: A simple cell: two pieces of different metals resting in dilute sulphuric acid.

Each group will need:

- 250 mL beaker
- strips of copper and zinc (galvanized iron may be used instead of zinc)
- dilute sulphuric acid
- 1.25 volt lamp and holder
- two alligator clips
- connecting wire

What to do

- Connect the metal strips to the lamp holder by alligator clips and connecting wires.
- Dip the metal strips in dilute sulphuric acid in a beaker. Make sure the strips do not touch one another. (See figure 7.14.)
- Repeat the experiment, using two strips of copper and two strips of zinc.

Questions

7.5 Did you notice anything happening in the beaker? Did any chemical action take place?

7.6 Did the bulb light? If it did, what is your conclusion about changing chemical energy into electrical energy?

7.7 What was the result when strips of the same metal were used? Can you write a conclusion about the possibility of generating electricity this way?

EXPERIMENT

7.4

Changing electrical energy into chemical energy

Each group will need:

- two pieces of sheet lead, as shown in figure 7.15 (next page)
- two thin strips of wood or cardboard
- 200 mL beaker
- two rubber bands
- 1.25 volt lamp and holder
- connecting wire
- two alligator clips
- power pack
- dilute sulphuric acid (S.G. 1.25)

What to do

- Set up the apparatus as shown in figure 7.15.
- Disconnect the lamp and connect the cell to a 4 volt direct current power pack. Switch on the power pack for 5 minutes.
- Switch off the power pack, disconnect it and connect the lamp again.

Questions

7.8 Did the bulb light when the apparatus was set up? If it did not, can you suggest a reason why it should light with the apparatus set up as in figure 7.14 and not with the apparatus as in figure 7.15?

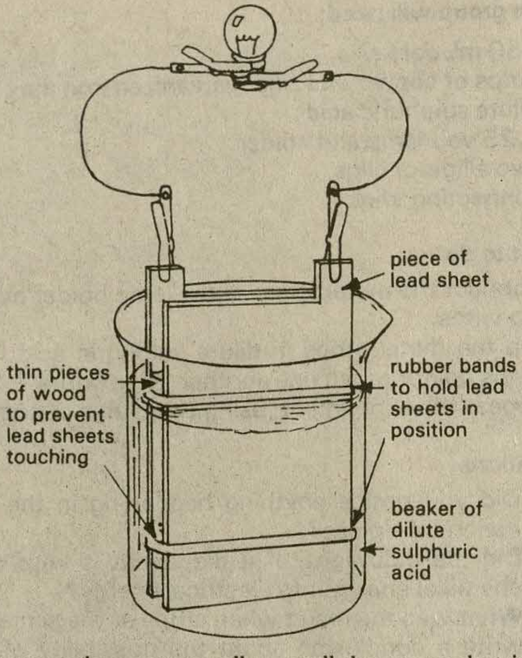

piece of lead sheet
thin pieces of wood to prevent lead sheets touching
rubber bands to hold lead sheets in position
beaker of dilute sulphuric acid

Figure 7.15: How to make a storage cell — a cell that stores electrical energy as chemical energy.

7.9 Did any change take place while the power pack was switched on? If it did, where did the energy come from to make the change?

7.10 Did the lamp light the second time it was connected? If it did, where did the energy come from to make it light?

7.11 Does this kind of cell have any use? Is it used in motor cars, for example?

Energy

1. Energy causes changes; for example, it can make things move.
2. Energy appears in many forms:
    - light energy
    - heat energy
    - electrical energy
    - chemical energy (due to composition)
    - kinetic energy (due to motion)
    - potential energy (due to position or compression)
    - nuclear energy
    - solar energy.
3. Energy cannot be created or destroyed. However, it can be changed from one form to another.

Spelling list

alligator
ammeter
concentrated
diesel
energy
explosion
ignite
kilowatt
kinetic
nuclear
nucleus
potential
smelting
solar
sulphuric
turbine

Things to do

7.12 Turn heat into sound energy by holding about a metre of downpipe vertically above a Bunsen burner flame.

7.13 Make a cotton-reel motor. Push a rubber band through the centre of a wooden cotton reel. Fasten the rubber band on one side of the reel with a drawing pin. Hold a washer on the other side of the reel. Slide a pencil through the loop of the rubber band so that the washer is between the pencil and the reel. Wind up the rubber band by turning the pencil. Release the motor on the bench. What sort of energy is stored in the motor?

7.14 Does your saliva contain energy? Moisten about a square centimetre of blotting paper by soaking it inside your mouth. Connect two wires to a microammeter. Place the blotting paper between a 10 cent and a 2 cent coin. Press the free ends of the wires against the coins with the blotting paper between them. What happens to the ammeter? Where does the energy come from?

7.15 Make a large diagram of the Snowy Mountains Hydro-electric Scheme. Use labels to indicate where energy changes take place. Show that all the energy may be traced back to the sun.

More questions

7.16 Write down a list of the various sources of heat in your home.

7.17 What kind of energy is possessed by water (a) at the top and (b) at the bottom of a waterfall?

7.18 Make two columns, one headed *kinetic energy* and the other *potential energy*. Write down the following phrases, placing each in its correct column:

(a) a moving bullet
(b) a coiled spring pushed down into a box
(c) a running broad-jumper immediately before he leaps from the ground
(d) an archery bow pulled taut
(e) a moving aircraft just before it takes off
(f) a child's swing at the top of its path
(g) a child's swing as it moves through the bottom of its path.

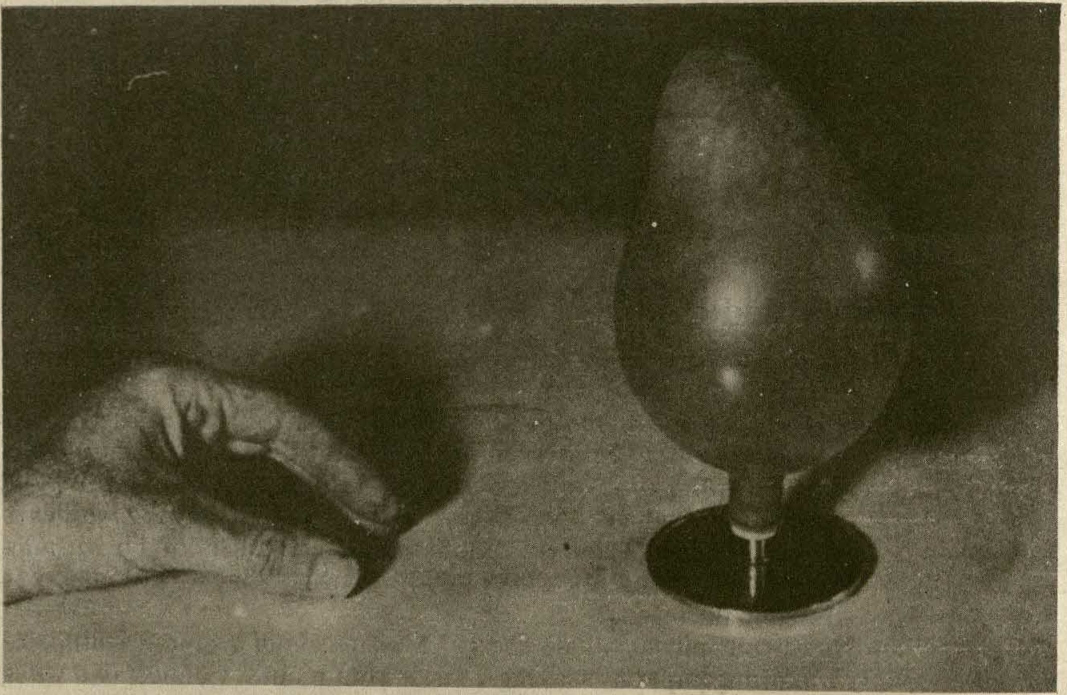


Figure 7.16: Moving objects tend to lose kinetic energy because of friction. When this happens, the kinetic energy changes to heat and the object slows down. The puck in the photo is riding on a cushion of air. Once set in motion it continues to move without loss of speed because there is no friction.

7.19 Coal is formed from plants and trees. What energy changes occur in converting the sun's energy into:
- (a) the energy stored in the coal
- (b) the energy used to boil the water at the power station
- (c) the kinetic energy of the steam from the boiling water
- (d) the kinetic energy of the turbines linked to the electric generators
- (e) the electrical energy used to operate a vacuum cleaner?

7.20 What changes occur in changing the sun's energy into:
- (a) the potential energy of water droplets in clouds
- (b) the kinetic energy of water flowing down from a high dam
- (c) the kinetic energy of an electric generator
- (d) the electrical energy used in a toaster?

7.21 Why is electricity the most widely used form of energy?

7.22 What energy change is taking place when saws and drills become hot? Does this change affect the efficiency of the saw or drill? How can the formation of heat be reduced?

7.23 What are solar heaters? How are they being used in Australia at present?

Test yourself (chapter 7)

Each part of questions 1 to 5 can be answered by supplying one word. Write down the missing word in your workbook.

1. Energy can make __________.
2. The type of energy possessed by:
   (a) a wound-up clock spring is __________.
   (b) chocolate is __________.
   (c) a bullet fired from a gun is __________.
3. In a torch, (a) __________ energy in the battery is changed into (b) __________ energy in the bulb.
4. The kinetic energy of a car is changed largely into __________ energy when the brakes are applied.
5. A man is carried up three floors in a lift. Name the kind of energy he has gained when he stops at the third floor.

In each of the following questions, choose the best answer and write its letter in your workbook.

6. An electric motor is used to:
   (a) create energy
   (b) produce electricity
   (c) produce mechanical energy
   (d) produce light.
7. A stone is pushed over a cliff. Halfway down the cliff we can say that the stone has:
   (a) lost potential energy
   (b) lost kinetic energy
   (c) gained energy
   (d) gained potential energy.
8. Petrol provides energy to move a car because:
   (a) petrol has kinetic energy
   (b) energy can be destroyed
   (c) energy can be changed from one form to another
   (d) petrol has no energy until it burns.

8

The air around us

We live in an ocean — an ocean of air. Fish also live in an ocean — an ocean of water. However, the fish live mostly at the top of their ocean, whereas we live at the bottom of ours. The ocean of air is called the *atmosphere*.

The ocean of water has a definite surface, so at any one place it has a definite depth. But the atmosphere has no definite surface. The higher one goes into the atmosphere, the thinner the air becomes; that is, the particles of which it is composed become further and further apart. But there is no place where the atmosphere suddenly ends.

Traces of air are known to exist as high as 800 kilometres above the earth's surface. Scientists have discovered this by measuring the height of auroras. These are glows in the sky caused by electricity acting on rarefied air. If there is no air there can be no auroras.

Air occupies space

Matter can be defined as anything that occupies space or has weight.

A simple experiment that shows that air takes up space is illustrated in figure 8.1. Notice that the air in the beaker

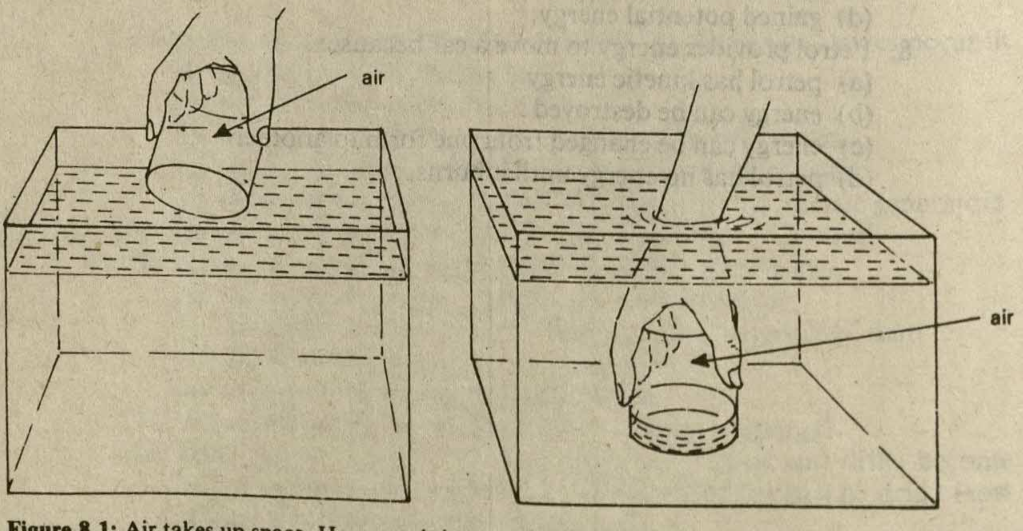


Figure 8.1: Air takes up space. However, it is compressed by the pressure of the water when the beaker is pushed beneath the surface.

holds the water back. However, the air is compressed into a smaller space by the pressure of the water acting upwards on it.

Have you ever noticed how difficult it is to fill a narrow-necked bottle with water by holding it under a tap? The space inside the bottle is filled with air, and this must escape if the water is to take its place.

Air has weight

Figure 8.2 shows apparatus that can be used to demonstrate that air has weight. A little water is added to the flask and boiled, so that the steam pushes out the air. While the steam is still issuing from the rubber tube, the flame is removed and the screw clip closed. When the steam condenses back to water, a near-vacuum is formed inside the flask.

The flask is then hung from one arm of a beam balance and weighed by adding weights to the other pan. The clip is then opened, allowing air to rush into the flask. When the balance is set swinging it can be seen that the flask is heavier. It is the air that has rushed in to fill the flask that has caused the increase in weight.

Air pressure

Air has weight and can therefore exert pressure. There are many simple experiments that demonstrate the pressure of air.

A little water is placed in a tin can that has a screw top. The screw top is set aside. The can is placed over a Bunsen burner and heated until the water boils and steam issues freely from the top. The Bunsen burner is then quickly removed and the cap screwed on very tightly. Cold water is run over the can, which is then allowed to stand. The sides of the can gradually cave in, as shown in figure 8.3.

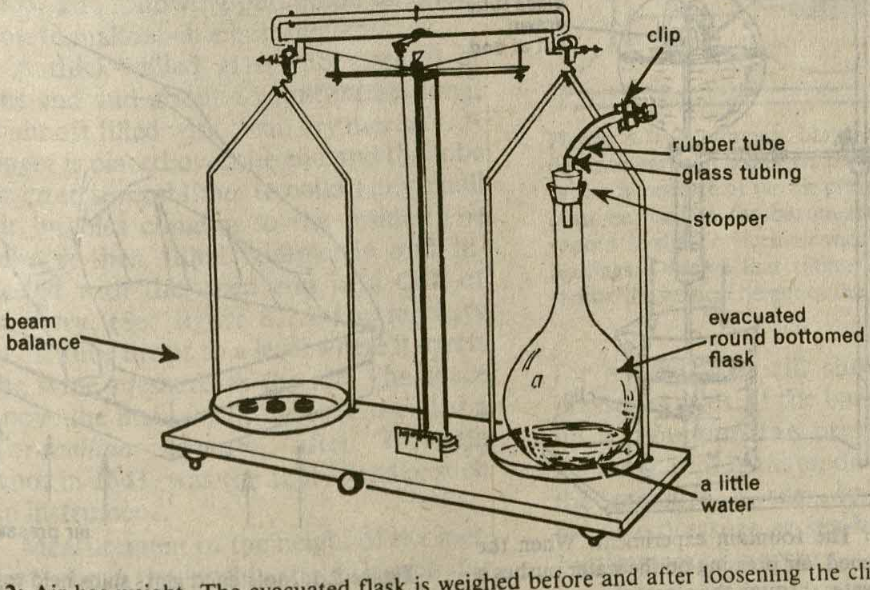


Figure 8.2: Air has weight. The evacuated flask is weighed before and after loosening the clip. Any difference in weight is due to the air that enters.

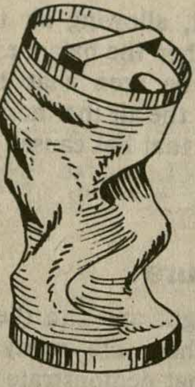


Figure 8.3: The tin can experiment. An evacuated can caves in under the pressure of the outside air.

Nearly all of the air is driven out of the can by the steam. When the can cools the steam condenses, creating a near-vacuum inside. The pressure of the surrounding air pushing in on all sides causes the can to collapse.

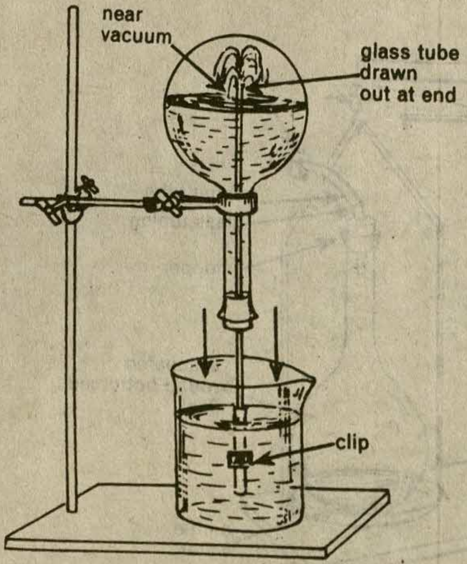


Figure 8.4: The fountain experiment. When the clip is loosened, air pressing on the water pushes a stream of water through the glass tube.

A demonstration using apparatus similar to that shown in figure 8.2 can produce a spectacular fountain of water. After the water has been boiling in the round-bottomed flask for a short time, the gas is turned off and the clip is tightened. The flask is allowed to cool and then inverted in the beaker of water, as shown in figure 8.4. The clip is then loosened. A fountain of water immediately gushes from the end of the glass tube. The water is pushed up the tube by air pressing down on the water in the beaker. It meets little resistance, since the space inside the flask contains very little air or water vapour.

Air pressure acted in all directions on the can to cause it to collapse. It acted down on the water surface in the fountain experiment, pushing water up the tube. Figures 8.5 and 8.6 show two more simple experiments that again demonstrate that air pressure acts in all directions.

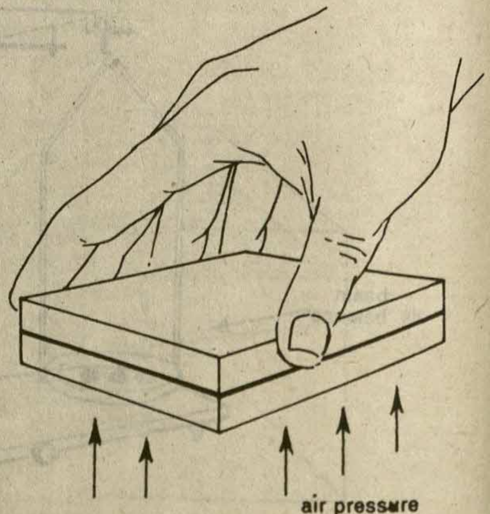


Figure 8.5: Moistened glass slabs held together by air pressure.

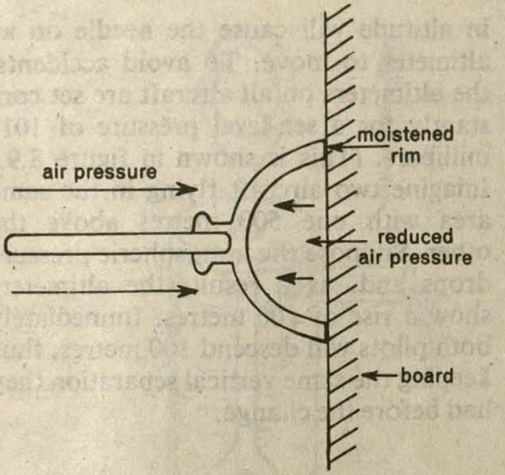


Figure 8.6: A rubber force-cup held to a board by air pressure.

Measuring atmospheric pressure

An instrument that measures the pressure of the atmosphere is called a *barometer*. In one kind of barometer the pressure of the atmosphere is balanced against a column of mercury in a glass tube. The following paragraph describes how to make such a barometer:

A thick-walled glass tube, sealed at one end and about 85 centimetres long, is almost filled with clean dry mercury. A finger is placed over the end and the tube inverted several times to collect any small air bubbles clinging to the inside. The tube is then filled completely and inverted with the open end in a dish of mercury. (See figure 8.7.) The mercury in the tube drops to a level where it exerts the same pressure as the air. The space above the mercury in the tube is called a *Torricellian vacuum*, after Torricelli who, in 1643, was the first to make such an instrument.

Measurement of the height of the mercury above the level in the dish each day for a few days will show that the air pressure varies. If the barometer is taken up a mountain the pressure is seen to decrease. If it is taken down a mineshaft the pressure is seen to increase. The average pressure at sea level is about 76 centimetres of mercury.

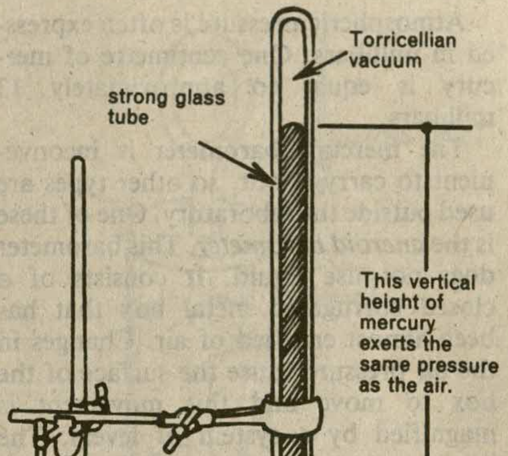


Figure 8.7: A mercury barometer. The vertical distance between the levels in the dish and in the tube is a measure of the air pressure. Dry mercury must be used in the barometer — air or water vapour in the Torricellian vacuum results in low readings. Observe that tilting the tube does not change the vertical height of the mercury column.

Atmospheric pressure is often expressed in millibars. One centimetre of mercury is equal to approximately 13 millibars.

The mercury barometer is inconvenient to carry about, so other types are used outside the laboratory. One of these is the *aneroid barometer*. This barometer does not use liquid. It consists of a closed corrugated metal box that has been almost emptied of air. Changes in the air pressure cause the surface of the box to move and this movement is magnified by a system of levers. The levers operate a pointer moving over a scale marked to read off the air pressure in centimetres of mercury. (See figure 8.8.)

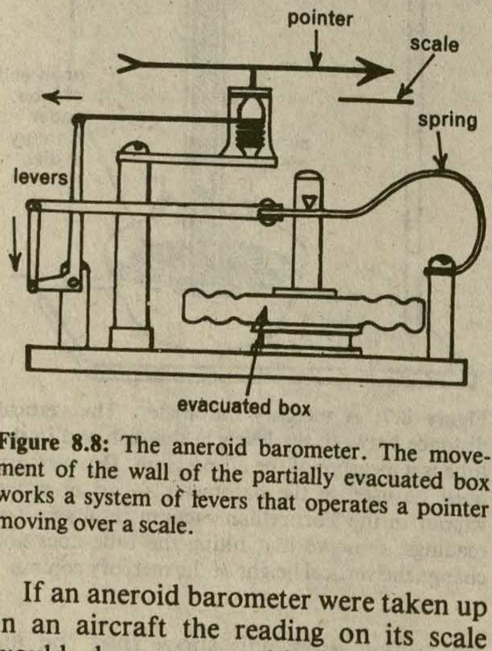


Figure 8.8: The aneroid barometer. The movement of the wall of the partially evacuated box works a system of levers that operates a pointer moving over a scale.

If an aneroid barometer were taken up in an aircraft the reading on its scale would decrease as altitude increased. This happens because air pressure becomes less as the plane ascends. Therefore by altering the units on the scale, the aneroid barometer can be used as an altimeter.

Changes in weather as well as changes in altitude will cause the needle on an altimeter to move. To avoid accidents, the altimeters on all aircraft are set constantly for a sea-level pressure of 1013 millibars. (This is shown in figure 8.9.) Imagine two aircraft flying in the same area with one 500 metres above the other. Suppose the atmospheric pressure drops and, as a result, the altimeters show a rise of 100 metres. Immediately both pilots will descend 100 metres, thus keeping the same vertical separation they had before the change.

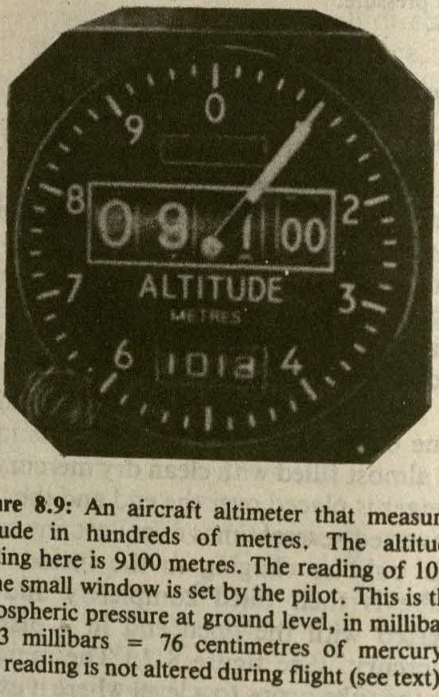


Figure 8.9: An aircraft altimeter that measures altitude in hundreds of metres. The altitude reading here is 9100 metres. The reading of 1013 in the small window is set by the pilot. This is the atmospheric pressure at ground level, in millibars (1013 millibars = 76 centimetres of mercury). This reading is not altered during flight (see text).

Use of air pressure

Many instruments and appliances depend on air pressure for their operation. The simple pump, for example, is a machine that uses the pressure of the air. Figure 8.10 shows a simple lift pump. In

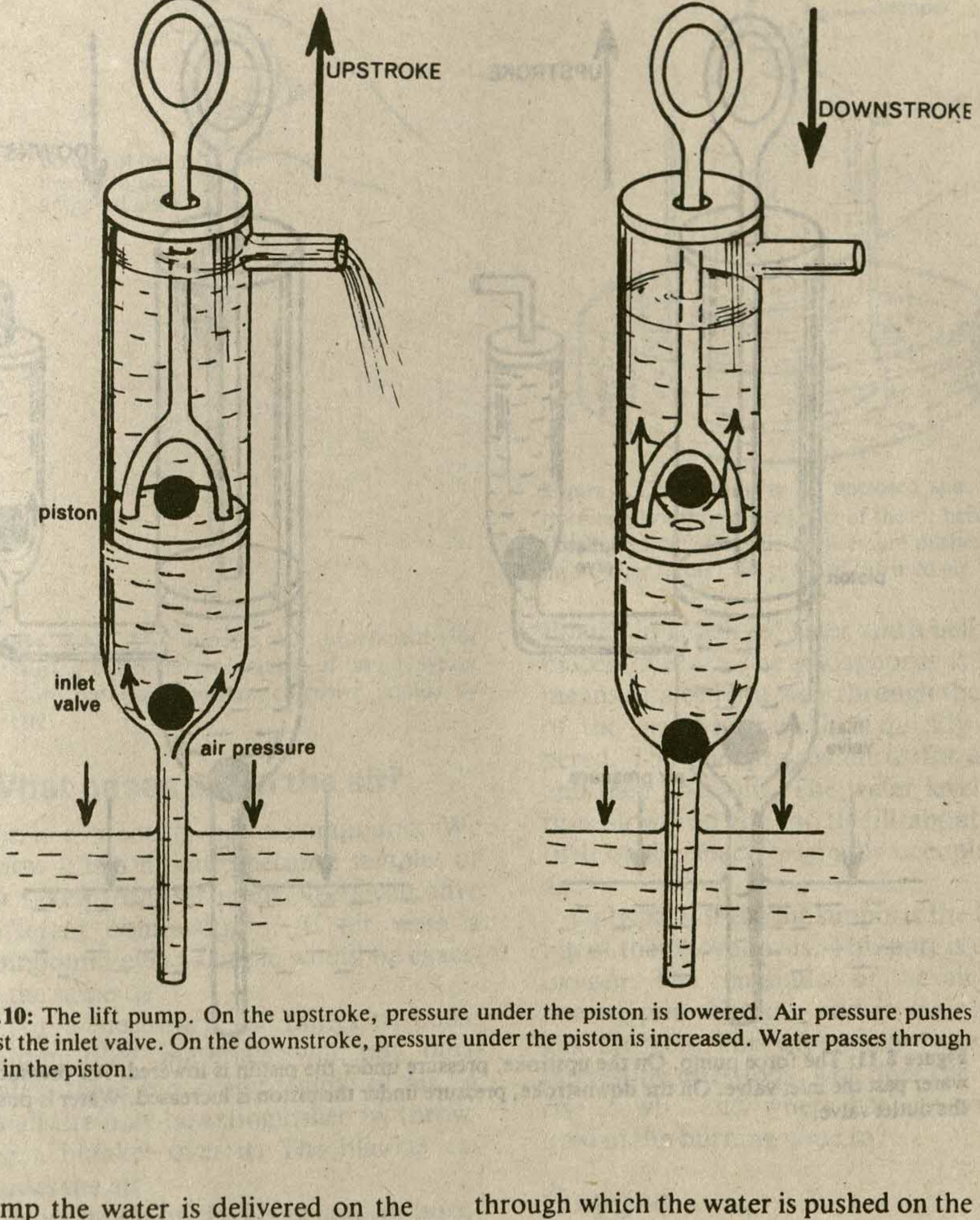


Figure 8.10: The lift pump. On the upstroke, pressure under the piston is lowered. Air pressure pushes water past the inlet valve. On the downstroke, pressure under the piston is increased. Water passes through the valve in the piston.

this pump the water is delivered on the upstroke and at the same time more water is pushed into the cylinder by air pressure.

Figure 8.11 shows another type of pump, which delivers on the downstroke. This is the force pump. It has no valve in the piston, but has a side arm through which the water is pushed on the downstroke. This arm has a valve to prevent the water running back.

Pipettes are instruments that deliver a certain volume of liquid when filled to a mark on the stem. They are filled by sucking on the stem to reduce the pressure inside. Liquid is then pushed in-

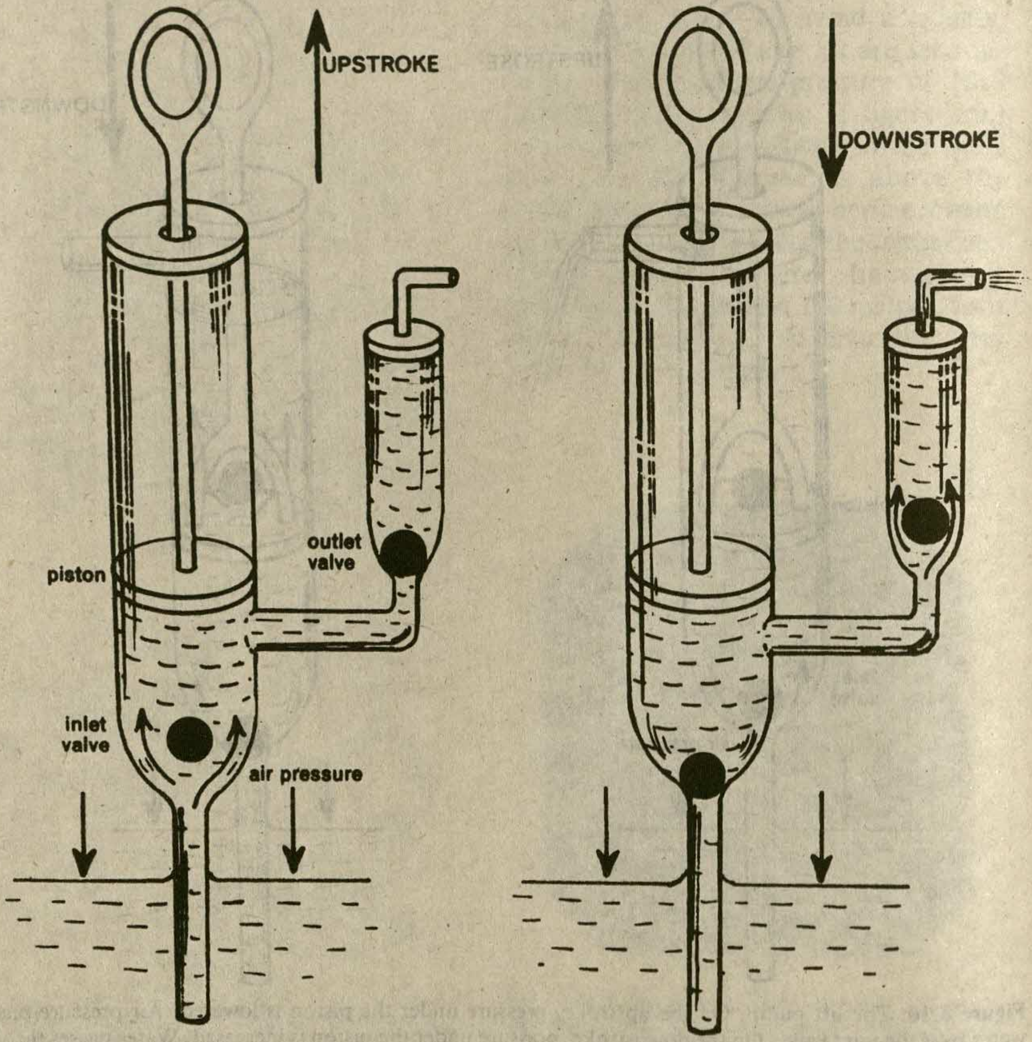


Figure 8.11: The force pump. On the upstroke, pressure under the piston is lowered. Air pressure pushes water past the inlet valve. On the downstroke, pressure under the piston is increased. Water is pushed past the outlet valve.

to the pipette by the pressure of the air outside. A finger is placed over the stem to keep the liquid in the pipette. To hold the volume stamped on the bulb, the pipette is first filled above the mark and liquid allowed to run out until the bottom of the meniscus coincides with the mark. (See figure 8.12.) When the finger is removed, the correct volume of liquid will be delivered without shaking or blowing into the pipette to remove the last drop.

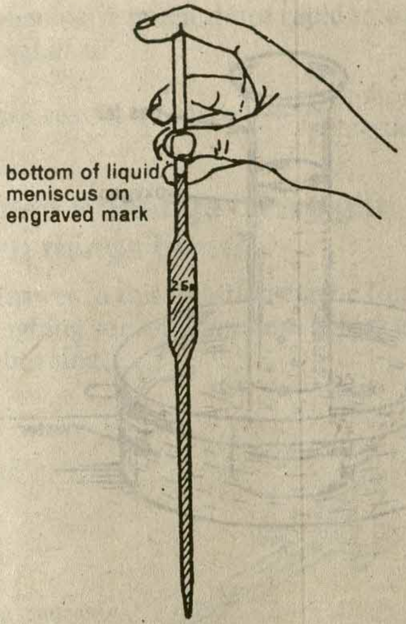


Figure 8.12: The pipette, an instrument for measuring out a certain volume of liquid. Never measure out poisonous or corrosive liquids by pipette.

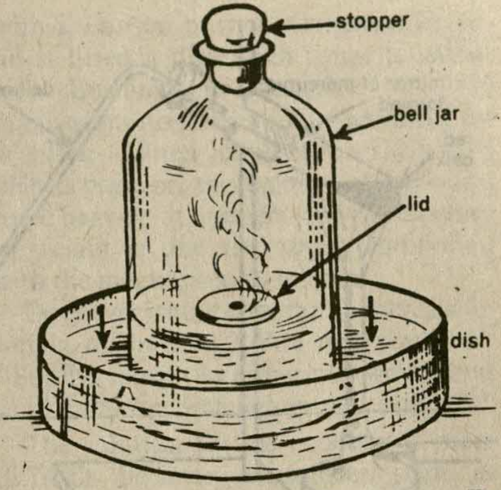


Figure 8.13: Burning in an enclosed space. The burning phosphorus uses part of the air before the flame goes out. Outside air pressure pushes water into the jar to take the place of the used air.

What gases are in the air?

Air is a mixture, not a compound. We know it is a mixture because samples of air taken from different places can have different compositions. If air were a compound every sample would be exactly the same.

Air is necessary for things to burn. Combustible materials will not burn unless there is a ready supply of air. A small fire may be extinguished by throwing a blanket over it. The blanket excludes the air.

How much of the air is used in burning? A simple experiment to find the answer consists of burning some phosphorus under a bell jar standing in water. (See figure 8.13.)

Burning in an enclosed space

A piece of phosphorus in a small lid is floated in a dish of water and a bell jar is placed over it. The phosphorus is lit by means of a red hot wire through the neck of the jar, which is then quickly stoppered. The phosphorus burns for a time and then goes out. The water level then rises slowly in the jar to fill about one-fifth of the space originally occupied by air.

Only part of the air supports the burning of the phosphorus. This part is called oxygen. The remainder of the air does not support burning and is mainly the gas nitrogen. This experiment raises two interesting questions: why does the water rise slowly, and where has the oxygen used in the burning gone to?

Oxygen

If mercury is heated gently in air it absorbs oxygen, like the phosphorus just mentioned, and forms a red powder. Priestley and Lavoisier found that by further heating this red powder, called red calx, they recovered both mercury and oxygen. (See figure 8.14.)

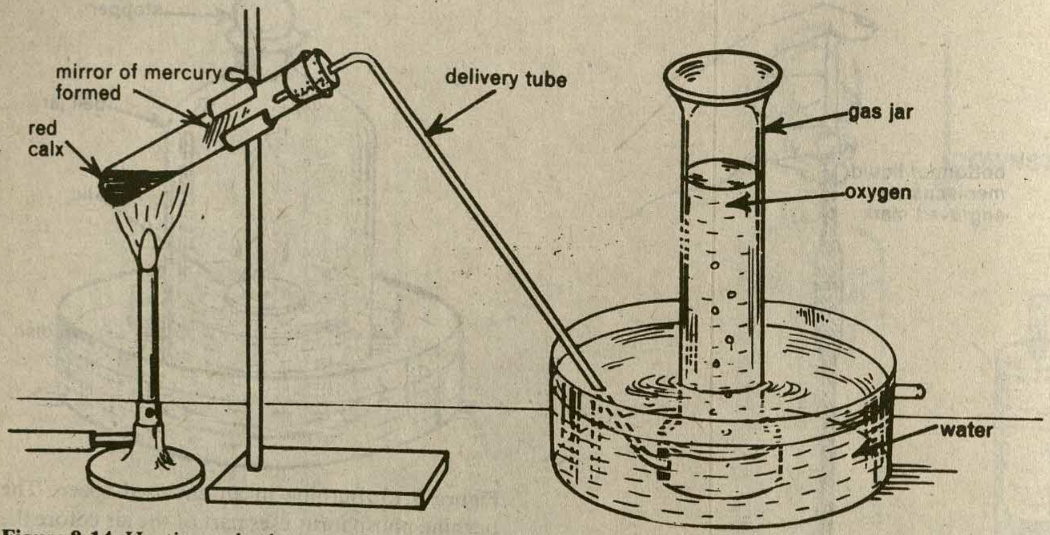


Figure 8.14: Heating red calx to produce mercury and oxygen.

Today we would heat less expensive substances than red calx to prepare oxygen. Such substances include red lead, potassium nitrate, potassium chlorate and Condy's crystals.

One method of preparing oxygen is to heat a mixture of potassium chlorate and manganese dioxide, using the same apparatus as shown in figure 8.14. The manganese dioxide speeds up the reaction without being changed itself. Such a substance is called a catalyst.

Properties of oxygen

Oxygen (the gas collected) is colourless and apparently insoluble in water (since it can be collected over water, as in figure 8.14). It is also odourless. (Care should be taken in smelling gases, since some are poisonous. Do not put your nose into a gas jar — just waft the gas towards you with your hand.)

Substances that burn in air burn more vigorously in pure oxygen. For example, a glowing splinter of wood bursts into flame when put into a gas jar of oxygen.

Glowing carbon also bursts into flame in oxygen. The product is carbon dioxide.

carbon + oxygen → carbon dioxide

Magnesium burns brilliantly in air with a bright white flame, forming a white ash of magnesium oxide. It burns even more vigorously in oxygen.

magnesium + oxygen → magnesium oxide

When heated, sulphur, a yellow powder, first melts and then burns slowly with a pale blue flame, forming sulphur dioxide, a colourless gas with a pungent odour. In oxygen sulphur burns brightly with a mauve flame.

sulphur + oxygen → sulphur dioxide

Red phosphorus burns with a yellow flame, forming phosphorus pentoxide.

The burning is much more rapid in oxygen than in air.

phosphorus + oxygen ⟶ phosphorus pentoxide

Is there a change of weight when things burn?

The answer to this question can be found by weighing some magnesium before and after burning.

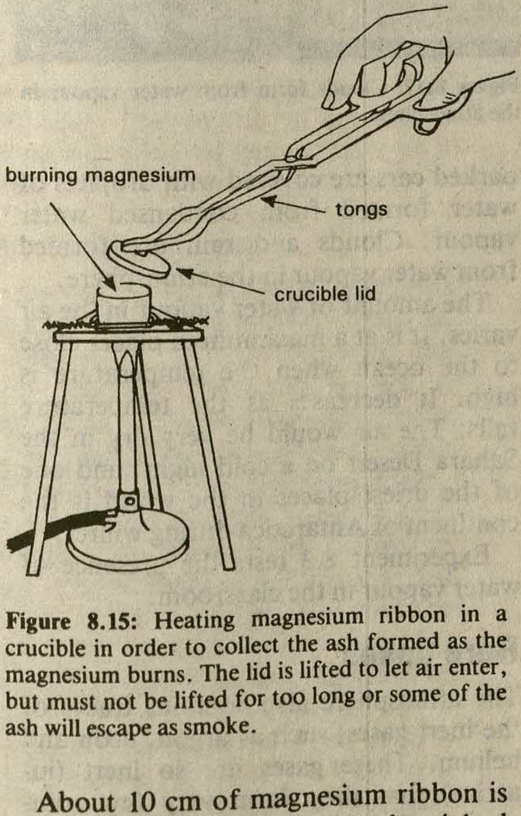


Figure 8.15: Heating magnesium ribbon in a crucible in order to collect the ash formed as the magnesium burns. The lid is lifted to let air enter, but must not be lifted for too long or some of the ash will escape as smoke.

About 10 cm of magnesium ribbon is crumpled into a loose ball and weighed in a crucible fitted with a lid. Balancing the weight of the crucible and contents with sand on a beam balance is accurate enough.

The crucible is placed on a pipeclay triangle on a tripod and heated strongly with a Bunsen burner. Occasionally the lid is lifted a little with tongs to admit air. Burning is complete if the magnesium no longer flares when the lid is lifted. When cool, the crucible is placed back on the balance. It is found to be heavier. It appears that the increase in weight is due to oxygen combining with the magnesium as it burnt.

Does everything that burns increase in weight on burning? You might answer, "Surely things like petrol, wood and candle wax become lighter on burning?"

The solution to this problem is more difficult because substances such as petrol and wood form gases as they burn. It was easy to show that magnesium oxide is heavier than magnesium because the oxide is a solid.

Figure 8.16 shows an apparatus that absorbs the gases formed as a candle

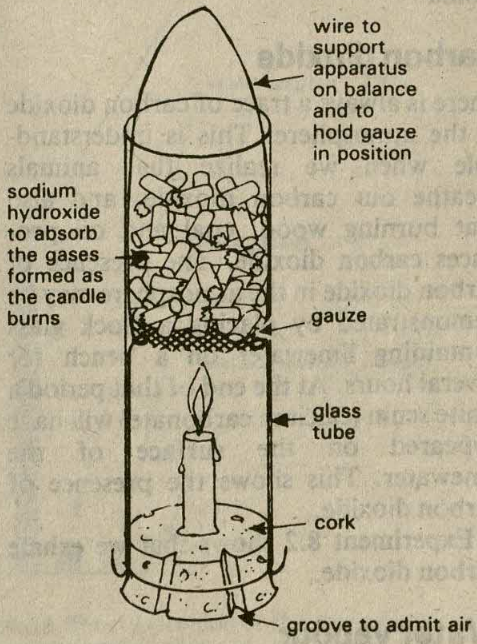

wire to support apparatus on balance and to hold gauze in position
sodium hydroxide to absorb the gases formed as the candle burns
gauze
glass tube
cork
groove to admit air

Figure 8.16: Apparatus used to show that the gases formed when a candle burns in air are heavier than was the original candle.

burns in air. The apparatus gets heavier as the candle becomes smaller. This shows that the gases formed by the burning candle are heavier than the candle itself. The burning of candle wax may be represented by the following statement.

$$\text{candle wax} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{steam}$$

Nitrogen

As was said earlier in this chapter, air is approximately one-fifth oxygen and four-fifths nitrogen. Nitrogen takes no part in burning, but is nevertheless a very important gas. All plants and animals need nitrogen compounds to keep them alive. Plants obtain nitrogen compounds from the soil. Animals obtain their nitrogen by eating plants or other animals. Common nitrogen fertilizers are nitrate of soda and sulphate of ammonia.

Carbon dioxide

There is always a trace of carbon dioxide in the atmosphere. This is understandable when we realize that animals breathe out carbon dioxide, and also that burning wood, coal and oil produces carbon dioxide. The presence of carbon dioxide in the atmosphere may be demonstrated by placing a clock glass containing limewater on a bench for several hours. At the end of that period a white scum (calcium carbonate) will have appeared on the surface of the limewater. This shows the presence of carbon dioxide.

Experiment 8.2 shows that we exhale carbon dioxide.

Water vapour

The presence of water vapour in the air is obvious. On a cold night windscreens of parked cars are covered with droplets of water formed from condensed water vapour. Clouds and rain are formed from water vapour in the atmosphere.

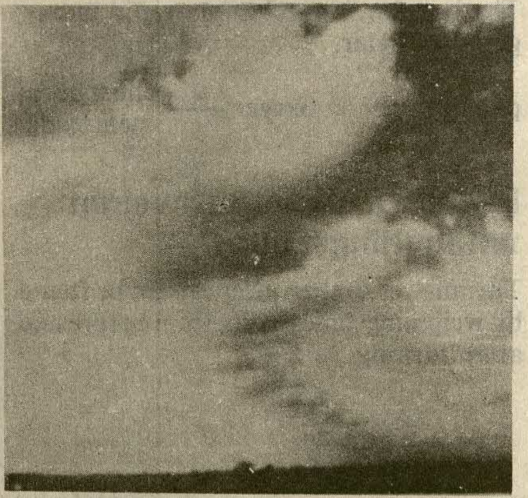


Figure 8.17: Clouds form from water vapour in the atmosphere.

The amount of water vapour in the air varies. It is at a maximum in places close to the ocean when the temperature is high. It decreases as the temperature falls. The air would be very dry in the Sahara Desert on a cold night, and one of the driest places in the world is the continent of Antarctica during winter.

Experiment 8.3 tests the presence of water vapour in the classroom.

Rare gases

The atmosphere also contains traces of the inert gases, such as argon, neon and helium. These gases are so inert (inactive) that they form very few compounds. They also form less than one per cent of the atmosphere. Nevertheless, they are very important commercially.

Helium, next to hydrogen, is the lightest known gas. Because it is so light and also is not flammable, it is used for filling airships and balloons.

Argon is used for filling electric lamps and for welding metals — such as aluminium — that burn when heated with an oxyacetylene torch.

Neon is well known for its use in neon signs.

The composition of the atmosphere

Earlier in this chapter we gave the composition of the atmosphere as approximately one-fifth oxygen and four-fifths nitrogen. We can now give a more detailed composition. Figure 8.18 does this by using a column graph. In this graph, water vapour is given as 2 per cent of the atmosphere. This would, of course, be more on a hot humid day and less on a dry cold day.

The rusting of iron

We are all familiar with problems created by the rusting of iron. Think of the enormous task of painting the Sydney Harbour Bridge to prevent it rusting. Rust in a motor car body can be quite dangerous, causing the car to break up, instead of crumpling, in an accident.

Figure 8.19 (next page) shows three experiments that indicate the factors in rusting. Figure A shows nails suspended in dry air. There is no rust, even after the test tube has been allowed to stand for months. Figure B illustrates the effect of leaving nails in a test tube with no air — only water vapour. No rust occurs. Figure C shows that rusting is like burning. The steel wool in the test tube containing air and water vapour rusts and, at the same time, the water level rises by approximately one-fifth of the volume of air. This leads us to conclude that both air and water are necessary for rusting and that rust is a compound of iron, oxygen and water.

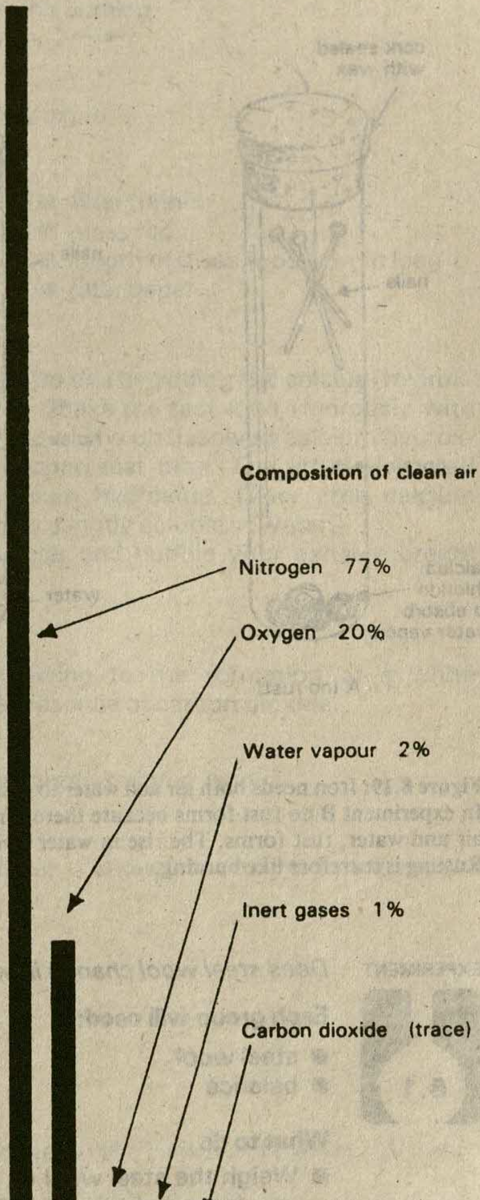


Figure 8.18: The composition of clean air on a day of average humidity. If the air sample had been taken in a city, it would, of course, contain pollutants from cars, factories and power stations.

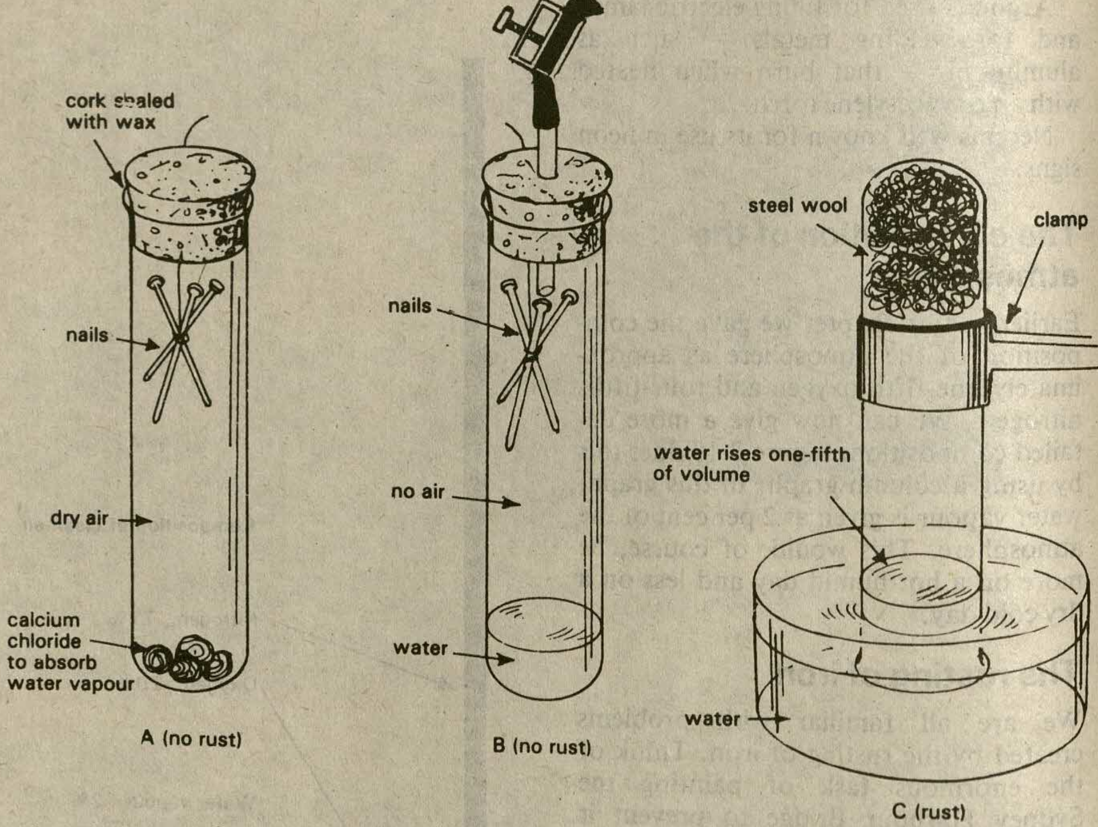


Figure 8.19: Iron needs both air and water to rust. In experiment A no rust forms because there is no water. In experiment B no rust forms because there is no air. In experiment C, where the test tube contains both air and water, rust forms. The rise in water level in C shows that iron combines with oxygen as it rusts. Rusting is therefore like burning.

EXPERIMENT 8.1

Does steel wool change in weight when it burns?

Each group will need:

- steel wool
- balance
- tongs
- Bunsen burner

What to do

- Weigh the steel wool on a balance. It will be sufficient to counterpoise it on a beam balance with dry sand.
- Set the steel wool alight by holding it in a Bunsen flame with a pair of tongs.
- When the steel wool is burnt and cool, replace it on the balance.

Questions

8.1 Was there any change in weight? If there was, can you explain it?

8.2 What is the colour of the oxide formed when steel wool is burnt? Why was the steel wool not burnt where the tongs held it?

8.3 Write a word equation to explain the burning.

iron + ? ⟶ ?

EXPERIMENT

8.2

Demonstrating that we exhale carbon dioxide

Each group will need:

- calcium hydroxide (enough to cover a 1 cent piece)
- two test tubes
- filter stand
- filter funnel
- glass rod
- length of glass tube 15 cm long
- filter paper

What to do

- First prepare a sample of limewater. Do this by adding the calcium hydroxide to a test tube half full of water. Shake the test tube vigorously with your thumb over the top. Allow most of the undissolved calcium hydroxide to settle, then filter into the second test tube. The filtrate is called limewater. It is a solution of calcium hydroxide. (Very little calcium hydroxide dissolves because it is only slightly soluble in water.)
- Place the glass tube in the limewater and bubble your exhaled breath through the limewater.

Question

8.4 Did the limewater turn milky owing to the formation of a white precipitate? This is a test for the presence of carbon dioxide.

EXPERIMENT

8.3

Showing that the air in the classroom contains water vapour

Each group will need:

- powdered bluestone (copper sulphate) — enough to cover a 1 cent piece
- crucible lid
- pipeclay triangle
- tripod
- Bunsen burner
- spatula (paddle-pop stick)
- 200 mL beaker
- four ice cubes

What to do

- Place a mixture of ice cubes and water in the beaker. Dry the outside and stand it in a draught-free position.
- Gently heat the powdered bluestone on the crucible lid on a tripod. Bluestone contains combined water. When heated, it loses this combined water and changes to a white powder.
- Examine the outside of the beaker. Has it become covered with a "mist"? Test to verify that this "mist" is condensed water vapour. Do this by pressing some of the heated bluestone (now white) into it with the spatula.

Question

8.5 Did the white powder turn blue? If it did, this is proof of the presence of water, which can be driven off by heating. The white powder formed is called anhydrous (meaning without water) copper sulphate. Water is the only substance that will change the white powder back to blue again.

The air around us

1. Air has weight and so exerts pressure.
2. The pressure of the atmosphere is measured with a barometer.
3. Normal atmospheric pressure will support a column of mercury 76 cm high.
4. Atmospheric pressure decreases as height above ground level increases.
5. Air is a mixture of nitrogen (about four-fifths by volume) and oxygen (about one-fifth by volume). Air also contains traces of carbon dioxide and water vapour, and argon and other rare gases.
6. When substances are burnt in air:
   - heat is produced
   - oxygen is used
   - oxides are formed
   - the oxides formed weigh more than the substances burned.

Spelling list

altimeter
aneroid
anhydrous
Antarctica
approximately
argon
aurora
balloon
barometer
calcium
catalyst
collapse
combustible
combustion
condense
corrugated
counterpoise
flammable
loosen
neon
nitrogen
oxygen
phosphorus
pipette
poisonous
sulphur
vacuum
vigorous

Things to do

8.6 Siphon some water from one large beaker to another by means of a rubber tube. Start to siphon by sucking water up and then allowing it to flow down the tube into the second beaker. Find out where the second beaker must be placed to give the fastest flow. When does the siphon stop working?

8.7 You may have a pair of Magdeburg hemispheres at your school. Fit them together and remove the air between them with a vacuum pump. How many people are required to pull them apart?

8.8 Examine a Fortin barometer, if there is one at your school. Find out how to use it to measure the atmospheric pressure.

8.9 Place a partly inflated balloon under a bell jar connected to a vacuum pump. What happens as air is pumped out of the bell jar? What happens when air goes into the jar?

8.10 Place a wooden ruler on a bench with one third projecting. Place a sheet of newspaper flat over the part of the ruler on the bench. Strike the projecting end of the ruler with a sharp downwards blow. Explain what happens.

More questions

8.11 Weather balloons usually burst when they reach an altitude of about 10 kilometres. Why?

8.12 Why is it necessary for a modern passenger aircraft to have a pressurized cabin?

8.13 A person's clothing catches alight. How would you put out the flames?

8.14 Why does a wind make a fire burn more vigorously?

8.15 Why does a crumpled newspaper burn more readily than a flat newspaper?

8.16 Name:
(a) the solid fuel
(b) the liquid fuel
(c) the gaseous fuel
most commonly used from day to day by the average household.

8.17 When pouring liquid from a tin, why is it better to have two holes than one in the tin?

8.18 Explain why your ears sometimes "pop" going down a steep mountain.

8.19 Name two occurrences that would tend to reduce the amount of oxygen in the air and increase the amount of carbon dioxide.

8.20 The weight of air on the roof of a house is about 1000 tonnes. Explain why roofs do not collapse under this weight.

8.21 Skin divers have descended as much as 70 metres in water. At this depth the pressure is about eight times the pressure at the surface of the water. What prevents the lungs collapsing and ear drums bursting under this pressure?

8.22 By referring to your library, find out how a hovercraft "flies".

Test yourself (chapter 8)

Write the answers to these questions in your workbook.

1. Two compounds exist everywhere in the atmosphere as gases. One is water. What is the other?

2. Name the most plentiful element in the air.
3. Give one reason why air is considered to be a mixture rather than a compound.
4. Name a gas formed when carbon burns in air.
5. Name the substance formed when magnesium burns in air.
6. What is the name of the instrument used to measure air pressure?
7. Figure 8.20 is a diagram of apparatus used to measure air pressure. Give names to the labels (a), (b), (c) and (d).

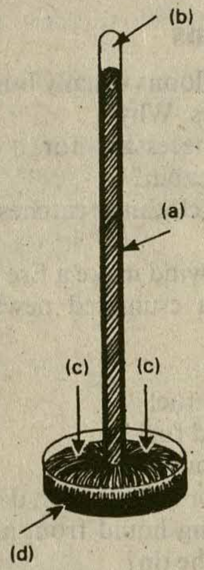


Figure 8.20

8. At sea level, normal atmospheric pressure is about how many centimetres of mercury?

Choose the best answer for each of the following questions and write its letter in your workbook:

9. The outsides of two identical cans are dried thoroughly. Ice and water are placed in the first; the second is left empty. After a time a difference between the two tins is noticed. The difference occurs because:
   (a) cold air around the first tin contracts and cools
   (b) there is less oxygen than nitrogen in the air
   (c) water vapour is present in the air
   (d) carbon dioxide is present in the air.

10. Carbon, copper and phosphorus are each burned separately in a jar of oxygen. In each of the three reactions the substance formed:
    (a) is a mixture
    (b) is an element
    (c) is a compound
    (d) is a metal.
11. Which of the following substances must be present in the air for a match to burn:
    (a) nitrogen
    (b) carbon dioxide
    (c) oxygen
    (d) argon?
12. A piece of magnesium is heated in a flame until it burns. A white powder is formed. In this reaction:
    (a) a compound is formed from two elements
    (b) one element is changed into another element
    (c) one compound is changed into another compound
    (d) a compound is changed into two elements.
13. Some iron nails are placed in a sealed vessel. The nails will rust if the vessel:
    (a) contains a little water but no air
    (b) contains air and a little water
    (c) contains air but no water
    (d) is full of water.

9

Temperature

Heat and temperature are not the same thing, although they are often confused in everyday language. For example, we may hear people talk about "blood heat" when they really mean blood temperature.

Heat, as we have seen in chapter 7, is a form of energy. When an object receives heat energy there is generally a rise in the temperature of the object. The higher the temperature of the object, the faster is the movement of its particles.

Temperature tells us much the same thing about heat energy as voltage does about electrical energy. You don't touch a wire carrying electricity at a high voltage because of the risk of having a large current of electricity pass through your body. In the same way, you don't touch a piece of metal that is at a high temperature because there will be a large flow of heat into your body, which will be very painful.

The experiment shown in figure 9.1 helps to explain further the difference between heat and temperature. The red-hot iron nail causes a much smaller rise in temperature in the beaker of water than does the iron cylinder, even though the latter is much colder than the nail. The iron cylinder obviously contained more heat than the nail.

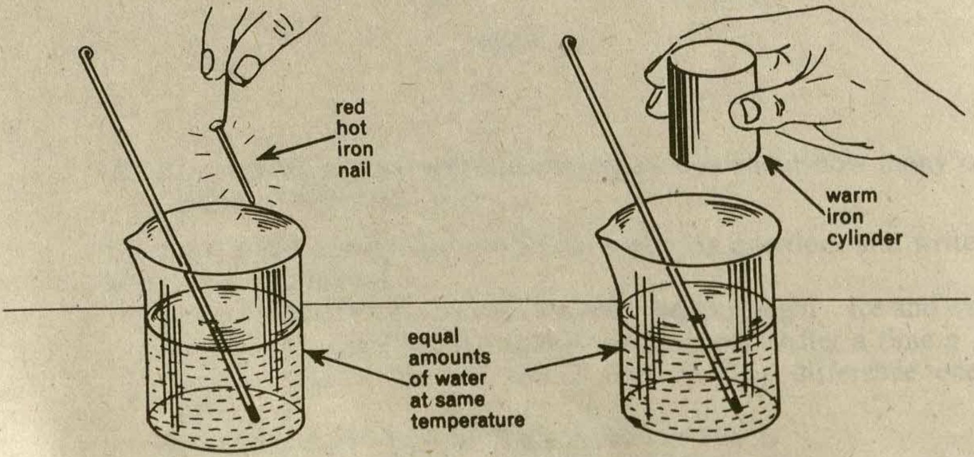

red hot iron nail
warm iron cylinder
equal amounts of water at same temperature

Figure 9.1: The difference between heat and temperature. The iron nail is at the higher temperature but the warm iron cylinder contains much more heat. When each is added to a beaker of cold water the temperature rise in the right-hand beaker is much greater than that in the left-hand beaker.

Early thermometers

An instrument that measures temperature is called a thermometer.

Evidence exists of a thermometer that was made as long ago as 200 B.C. Galileo made a thermometer in A.D. 1592 that was similar to the earlier one. Figure 9.2 is a sketch of Galileo's thermometer. To fill the tube with the coloured water, Galileo first placed his warmed hands around the bulb at the top. Because of expansion, some air was forced out. When the bulb was allowed to cool with the end of the tube in the bottom vessel, some coloured water was pushed up the stem. This was an air thermometer, which worked on the principle that the higher the temperature the lower the level of the water in the stem.

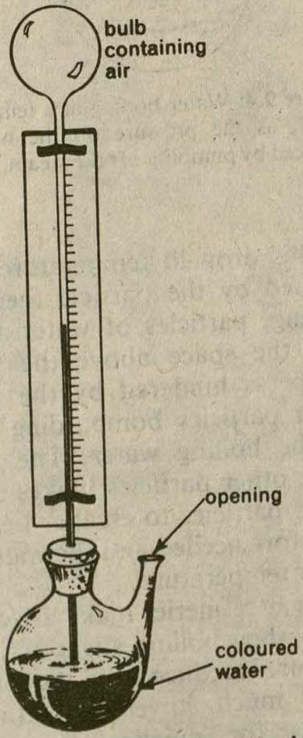


Figure 9.2: Galileo's thermometer. The level of the water in the glass tube fell as the temperature rose. The thermometer had no standard scale.

Galileo's thermometer had two faults. The level of the water in the tube changed not only with temperature, but also with changes in atmospheric pressure. As well, it was not standardized; a reading on Galileo's thermometer could not be compared with a reading on another such thermometer without placing the two thermometers side by side.

Standard scales

One of the first attempts to standardize thermometers was made by Dalence in 1688. He proposed that two points should be marked on the scale, the melting point of ice and the melting point of butter, the space between these two points to be divided into twenty parts. The lower fixed point proved satisfactory but the higher point was unsatisfactory. Butter is not a pure substance; it is a mixture and has no sharp melting point. As well as this, the composition of butter varies from place to place.

In 1714 Gabriel Fahrenheit, a German merchant interested in science, suggested the temperature of human blood as the higher fixed point. He also proposed a third point, which he called the point of greatest cold. This scale is shown in figure 9.3.

Fahrenheit's thermometer was sealed and so was not affected by atmospheric pressure. He chose alcohol instead of air as the expanding fluid and used his thermometer with the bulb at the bottom.

Anders Celsius in 1742 proposed a scale with the zero at the melting point of ice and the hundredth degree mark at the boiling point of water.

About this time also, mercury came to be used in preference to alcohol as a liquid for thermometers.

The Celsius scale is used in most countries today.

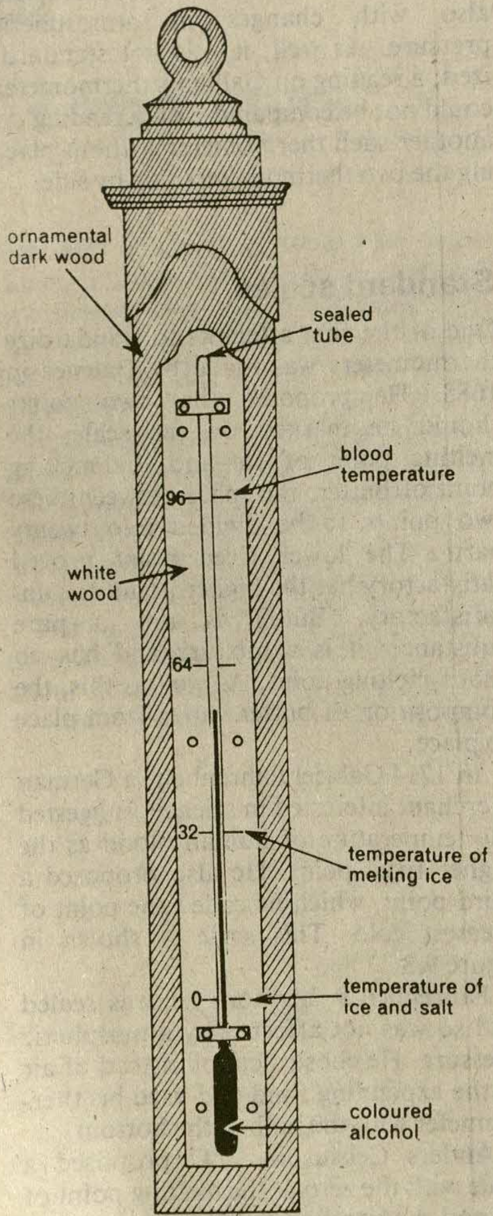


Figure 9.3: Fahrenheit's thermometer, 1714. Fahrenheit divided his scale into three equal parts. He had three fixed points. Blood temperature and the temperature of ice and salt are not used as fixed points today.

Effect of change in pressure on the boiling point of water

If the steam and air are pumped off the surface of water as it is boiling, the temperature at which the water boils will drop. (See figure 9.4.)

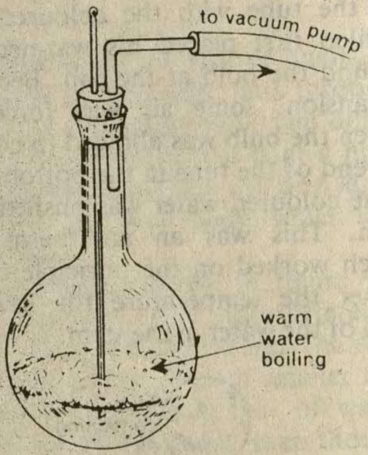


Figure 9.4: Water boiling at a temperature below 50°C, as the pressure on the boiling water is reduced by pumping off the steam.

This drop in temperature can be explained by the particle theory. During boiling, particles of water are escaping into the space above the water. This escape is hindered by the presence of other particles bombarding the surface of the boiling water. The removal of these other particles makes it easier for water particles to escape. Less energy is therefore needed and the water boils at a lower temperature.

Sugar refineries make use of this principle when boiling sugar solutions. The pressure is reduced and the solution boils at a much lower temperature. This makes for quicker evaporation and prevents charring of the sugar. (See figure 9.5.)

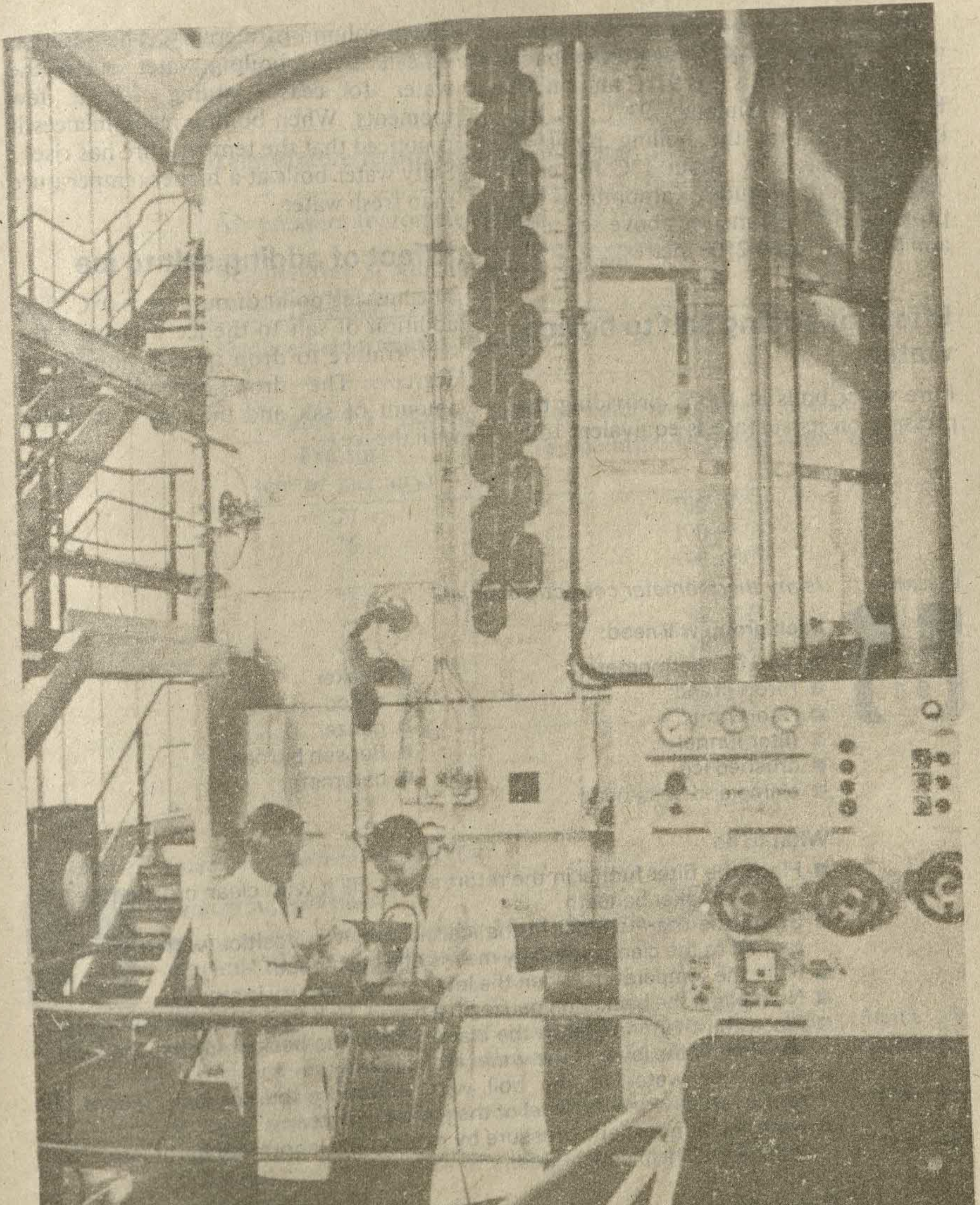


Figure 9.5: Vacuum pan used for boiling sugar solution. The pressure inside this pan will support a column of mercury only 10 centimetres high. (Photo courtesy Colonial Sugar Refining Company Ltd)

At sea level the boiling point of water is approximately 100°C; at Katoomba in the Blue Mountains it is 97°C and on Mt Kosciusko approximately 93°C. It has been found that the boiling point of water decreases by about 1°C for each 300 metres of altitude. Katoomba is approximately 1000 metres above sea level and Mt Kosciusko 2100 metres.

Effect of adding salt to boiling water

Pure water boils at 100°C providing the pressure on its surface is equivalent to a 76 cm column of mercury. The addition of salt to the boiling water causes the water to cease boiling for a few moments. When boiling recommences it is noticed that the temperature has risen. Salty water boils at a higher temperature than fresh water.

Effect of adding salt to ice

The melting point of pure ice is 0°C. The addition of salt to the ice will cause the temperature to drop quite a number of degrees. The drop depends on the amount of salt and the way it is mixed with the ice.

EXPERIMENT

9.1

Is my thermometer correctly marked?

Each group will need:

- 110°C thermometer
- retort stand
- retort ring
- filter funnel
- crushed ice
- clamp and boss-head
- beaker
- tripod
- gauze
- Bunsen burner
- barometer

What to do

- Place the filter funnel in the retort stand. Fill it with clean crushed ice and place a beaker beneath.
- Stand the thermometer in the ice, holding it in position with a clamp attached to the clamp stand by means of a boss-head.
- Note the temperature when the level of the mercury is steady.
- Next place the beaker on gauze on a tripod. Half fill it with distilled water.
- Place the thermometer in the clamp above the beaker so that the bulb is well below the level of the water in the flask.
- Bring the water to the boil with a Bunsen burner and record the temperature when the level of the mercury is steady.
- Note the atmospheric pressure by reading the laboratory barometer. Your teacher will help you do this.

Questions

9.1 Was your thermometer correct at the lower fixed point? If it was, it should have read 0°C. If it was not correct, what was the error? The error is positive if the reading is above 0°C and negative if below 0°C.

9.2 What was the reading on your thermometer when it was immersed in boiling water? Copy and complete the following table. You will need to refer to table 9.1.

Temperature recorded in boiling water	°C
Air pressure (barometer height)	cm
Temperature at which water is known to boil at this pressure	°C
Deduced error on my thermometer	°C

Table 9.1 Boiling point of water at different pressures

Pressure (cm of mercury)	Temperature at which water boils
77	100.4°C
76	100.0°C
75	99.6°C
74	99.2°C
73	98.8°C
72	98.4°C
71	98.0°C
70	97.6°C

EXPERIMENT

9.2

Does exercise make you hotter?

Each group will need:

- one clinical thermometer (or 110°C thermometer)
- a little methylated spirits in a beaker

What to do

- Record the temperatures of various members of your group. Shake the thermometer downwards after each reading and sterilize it by washing it in methylated spirits.
- Have these people run around in sunshine so that they are perspiring freely.
- Record the temperature of each person as he or she comes in from the exercise.

Question

9.3 Did exercise make you hotter? If it did not, how does the body get rid of excess heat generated by exercise?

Temperature

1. The temperature of an object tells us whether it will give out heat to, or take in heat from, its surroundings.
2. Thermometers have two fixed points:
   - M.P. (melting point) of ice — 0°C
   - B.P. (boiling point) of water at 76 cm pressure — 100°C.
3. Dissolved salt raises the B.P. and lowers the F.P. (freezing point) of water.
4. Lowering the pressure lowers the B.P. of water.

Spelling list

atmosphere
Celsius
clinical
degree
Fahrenheit
Galileo
mercury
standardize
temperature
thermometer

Things to do

9.4 Make an automatic fire alarm. (Refer to figure 9.6.) The bimetal strip curves as the temperature rises. When you first try out your alarm you may find the strip curves downwards instead of upwards when heated. All you have to do is turn the strip over so that it curves up when heated, as in a fire.

9.5 Make a model pyrometer as shown in figure 7.13 (page 69). Do you think this apparatus could be used to measure temperature?

9.6 Make an air thermometer by fitting a flask with a rubber stopper and a long glass tube. Invert the flask and clamp it in a retort stand so that the end of the tube stuck in the flask is below the level of some coloured water in a beaker. Drive some of the air out of the flask by heating it with a rag soaked in hot water. When the flask cools, coloured water will rise in the tube. Fix a piece of cardboard to the glass tube with Sellotape. Use an ordinary 110°C thermometer to mark two temperatures on the cardboard — one in hot sunlight and the second in a cold room. Using these two temperatures, make a scale on the cardboard.

9.7 How good is your skin as a thermometer? Fill three beakers with water — one with hot water, one with warm and the third with cold water. Put one hand in the hot water and the other in the cold for several minutes. Now place each hand in turn in the warm water. What do you notice? Can you explain it?

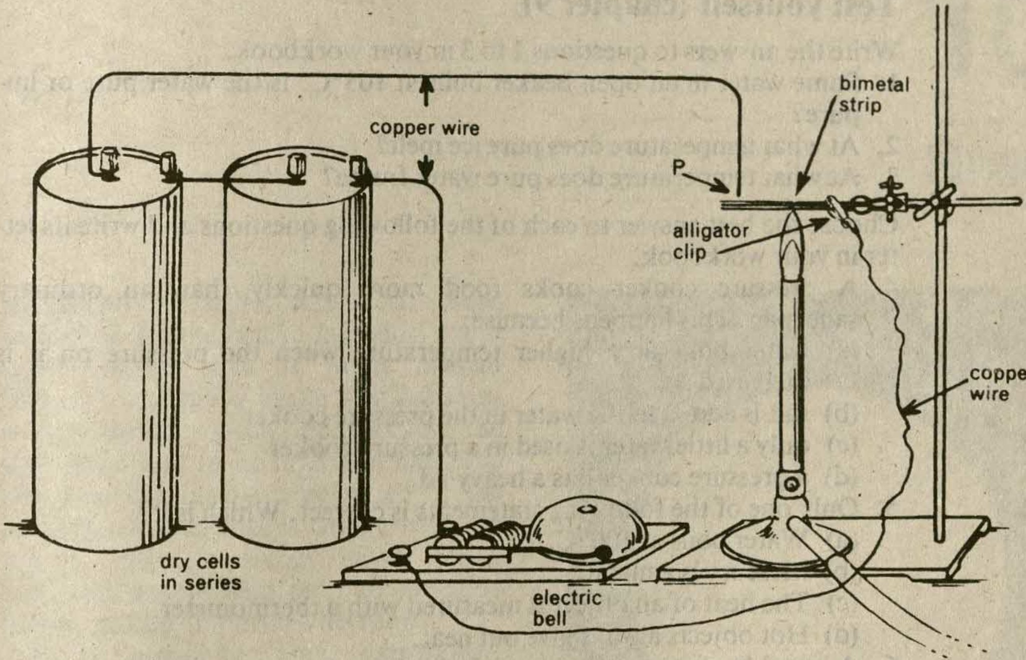


Figure 9.6: The electric fire alarm. When heated, the bimetal strip bends and makes contact at P. This completes the circuit and the bell rings.

More questions

9.8 Do all mammals have the same body temperature as humans? What is the body temperature of small birds? What is the body temperature of a penguin? How do penguins survive the Antarctic winter?

9.9 What is the body temperature of a whale? A whale spends a lot of time in polar waters. What keeps it warm?

9.10 Reptiles are often referred to as cold-blooded animals. What happens to a snake during a heavy frost? Why doesn't it freeze to death? Find out about the life habits of snakes.

9.11 Food will not cook properly if boiled in water in an open vessel on Mt Everest. Why?

9.12 How does a pressure cooker work? Why does it cook food more quickly? What prevents it exploding?

9.13 Imagine an open can of water placed on the moon in sunlight. What would happen?

9.14 Mercury boils at 357°C. Obviously a mercury thermometer cannot be used to measure temperatures of furnaces. Refer to your library to find out what methods are used for measuring very high temperatures.

Test yourself (chapter 9)

Write the answers to questions 1 to 3 in your workbook.

1. Some water in an open beaker boils at 105°C. Is the water pure or impure?
2. At what temperature does pure ice melt?
3. At what temperature does pure water freeze?

Choose the best answer to each of the following questions and write its letter in your workbook.

4. A pressure cooker cooks food more quickly than an ordinary saucepan. This happens because:
   (a) water boils at a higher temperature when the pressure on it is increased
   (b) salt is added to the water in the pressure cooker
   (c) only a little water is used in a pressure cooker
   (d) a pressure cooker has a heavy lid.
5. Only one of the following statements is correct. Which is it?
   (a) Water boils at 100°C.
   (b) Mercury is a metal.
   (c) The heat of an object is measured with a thermometer.
   (d) Hot objects always give out heat.
6. A metal bucket of warm water holds more heat than a crockery cup of boiling water because:
   (a) the boiling water is at a higher temperature
   (b) the cup of boiling water will cool down more quickly
   (c) a bucket holds more water than a cup
   (d) metal feels hotter than crockery.

10

Stars

People, from earliest times, have been interested in the stars. Legends about stars became part of many ancient religions and quite important decisions were sometimes postponed because the stars were said to be unfavourable. The idea that the future is governed by the positions of the stars is the basis of the subject called astrology. Even today there are people who refer to the stars before making important decisions.

From astrology grew astronomy. Astronomy is the careful and systematic observation of the stars. It is one of the sciences, unlike astrology.

Stars

The sun is a star, though we do not usually think of it as a star. There are two reasons for this. The first concerns distances. The sun is about 150 million kilometres from the earth. The nearest star to the earth, after the sun, is Proxima Centauri. This is about 50 000 000 million kilometres away. Such distances are difficult to appreciate, so a comparison may help. If we imagine the sun to be on the other side of the street, then on the same scale, Proxima Centauri would be 6500 kilometres away. This helps us to appreciate the vast emptiness of the universe. As the imagination travels through space from star to star, there is nothing and nothing again for countless millions of kilometres.

Because the sun is so very much closer to us than any other star, it is also very much brighter. This is why we do not see stars during daytime. It is the other reason for our not thinking of the sun as a star.

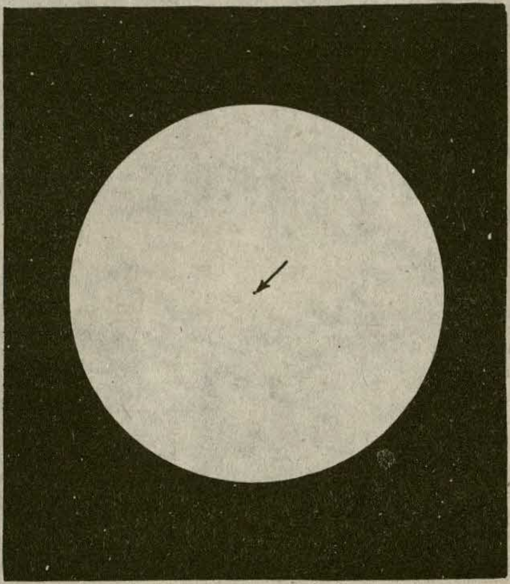


Figure 10.1: This drawing shows the almost unbelievable size of the sun when compared to the earth. Here the sun and the earth are drawn to the same scale. The earth is the dot at the centre.

The visible stars are suns, that is, large masses of very hot matter. The energy radiating from the stars is mainly light and heat formed from the atomic energy within the stars themselves. Our sun is an average-sized star but still its size is fantastic when compared with the size of the earth. (See figure 10.1.) There are stars,

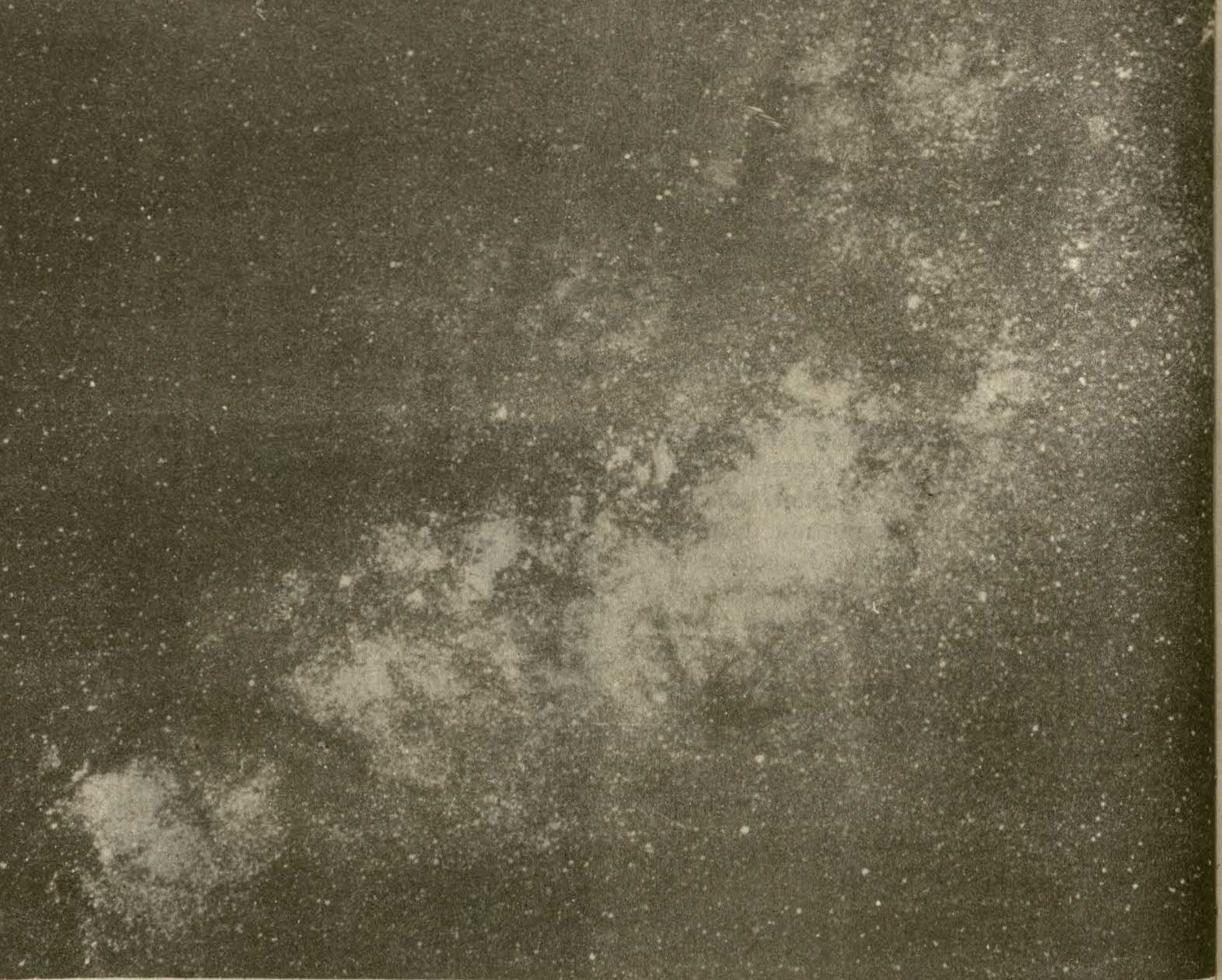


Figure 10.2: Star clouds in the Milky Way, Sagittarius region. Sagittarius is a constellation near the tail of the Scorpion. (Photo courtesy Mount Wilson and Palomar Observatories)

however, with diameters hundreds of times as great as the diameter of the sun. Such a star is Antares. (See figure 10.7, facing page 184.)

The Milky Way

The full beauty of a starry night is only appreciated by looking at the sky away from the smog and lights of cities. (See figure 10.2.) Close inspection will show that it contains very many stars, some very bright but most rather faint. The stars appear closest together in a bright band that stretches right across the sky. This band is called the Milky Way and it has been estimated that it contains the equivalent of 100 000 million suns.

Although we do not normally see it, the Milky Way also stretches across the daytime sky. The brightness of the sun prevents our seeing it.

Movement of the stars

The sun is a star. It rises in the east and

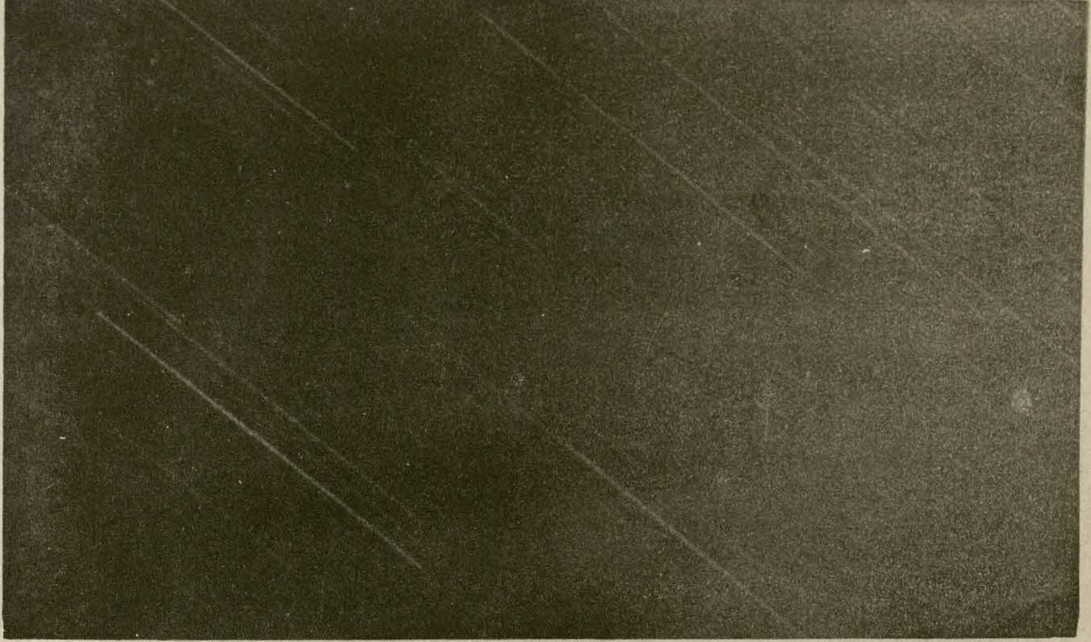


Figure 10.3: Stars rising in the north-east. This photograph was taken by leaving the shutter of the camera open for 45 minutes. This is why the stars are trails of light rather than points.

sets in the west. Does this mean that all stars rise in the east and set in the west? Not quite. A star that rises in the east moves in a huge arc overhead and eventually sets in the west. But stars rising in the south and north move in smaller arcs in the sky. Stars rising in the south-east set in the south-west and stars rising in the north-east set in the north-west.

Figure 10.3 is a photograph of star trails looking towards the north-east. The photograph was taken by leaving the shutter of the camera open for 45 minutes.

Constellations

During early historical times, people imagined figures and scenes to exist in the patterns of the stars. Such patterns or groups of stars are called constellations. Figure 10.4 shows a picture of Orion, the Great Hunter, and the way the stars have been used to outline him.

Orion can be seen during summer and autumn. Figure 10.6 (facing page 184)

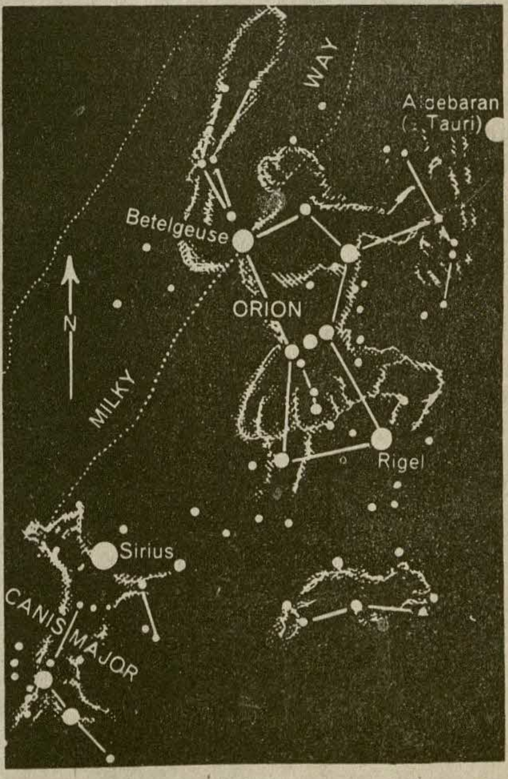


Figure 10.4: The constellation of Orion, the Hunter.

shows Orion setting in the west early in the evening during May.

Another well-known constellation is Scorpius—the Scorpion. The Scorpion with its two antennae and long curved body can be seen high overhead early on winter nights.

Crux—the Cross—is the best known of all constellations in the southern hemisphere. This group with its two Pointers can be seen low in the southern sky early on summer nights. (See figure 10.5, facing page 184.) The Cross and its Pointers form part of a larger constellation called Centaurus.

Colour of stars

Close examination of individual stars reveals that many are coloured, the colours ranging from red through orange, yellow and white, to blue. The accepted theory to explain these colours is that difference in colour is caused by difference in temperature, the hottest stars being blue and the least hot being red.

Distance of stars from earth

These distances are so great that it is rather meaningless to give them in kilometres. The unit commonly used is the light year. One light year is the distance covered by light travelling for one year. Light travels at 300 000 kilometres per second. Therefore one light year

$= 300\,000 \times 60 \times 60 \times 24 \times 365$ km

$= 9\,000\,000\,000\,000$ km (approx.).

Naming stars

The brightest stars in the sky are called stars of the first magnitude. Stars fainter than sixth magnitude cannot be seen without the aid of a telescope. In this chapter we shall name only first magnitude stars.

The brightest star in a constellation is given the prefix *alpha*. The second brightest has the prefix *beta*. Alpha (α) and beta (β) are the first two letters of the Greek alphabet.

Some first magnitude stars

Alpha Centauri is the brightest star of Centaurus. Alpha and Beta Centauri are the two Pointers to the Southern Cross. Alpha Centauri is really a double star, that is, two stars revolving around each other. The two stars can be seen separately through an average telescope.

Alpha Crucis—the brightest star in Crux, the Southern Cross—is a brilliant double star.

The brightest star in Scorpius is a huge orange star called Antares. It is so large that, if placed in the present position of the sun, its outer edge would lie beyond the planet Mars. Betelgeuse—the brightest star in Orion—is another huge star like Antares.

One of the hottest stars is Rigel. This is a blue-white star, the second brightest star in Orion. Rigel is pouring out as much energy as 25 000 of our suns.

Our list of first magnitude stars would be incomplete without the two brightest stars in the sky—Sirius and Canopus. These two brilliant stars lie between Orion and the Southern Cross and are easily identified during most nights of the year. (See figures 10.8 and 10.9.)

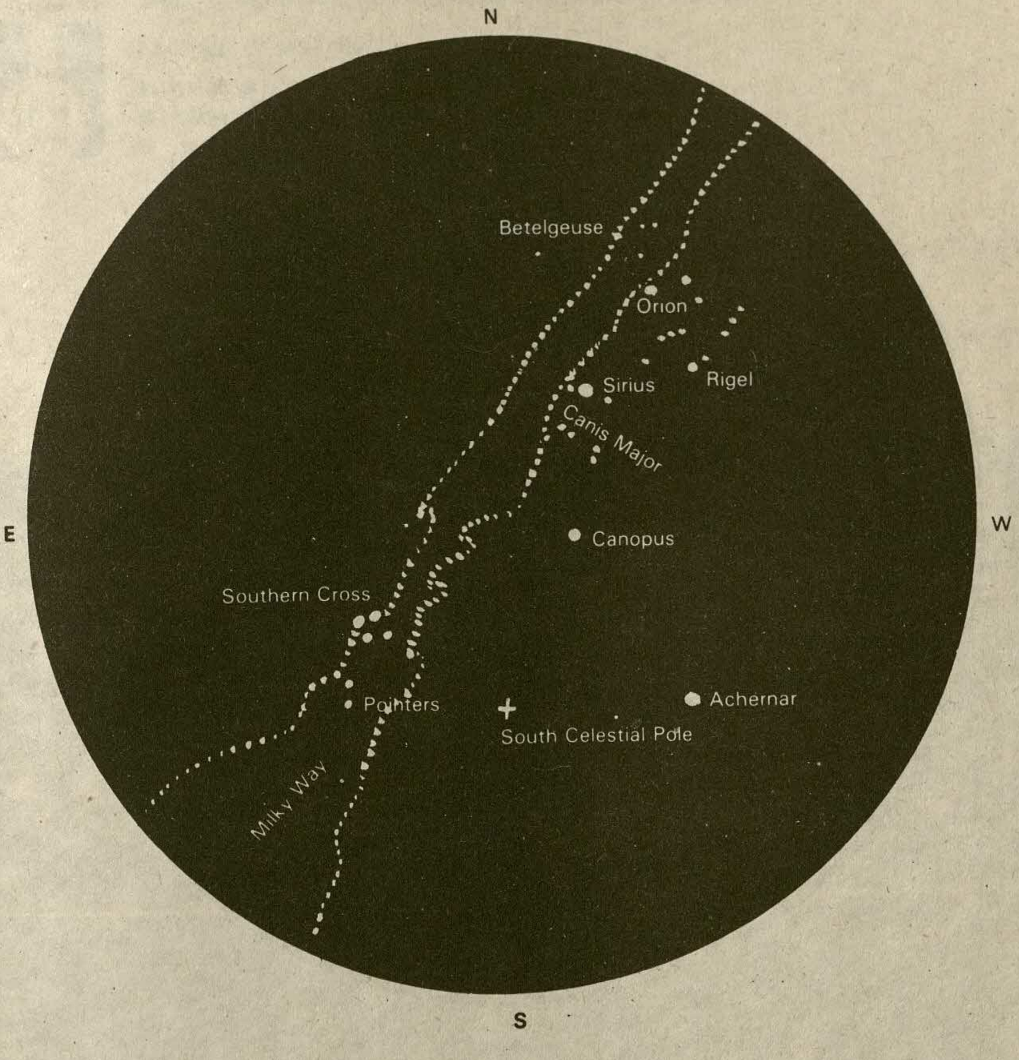


Figure 10.8: The evening sky in autumn — about 8.30 p.m., mid-March. When facing south hold the chart so that "S" is at the bottom; when you are facing east "E" should be at the bottom, and so on.

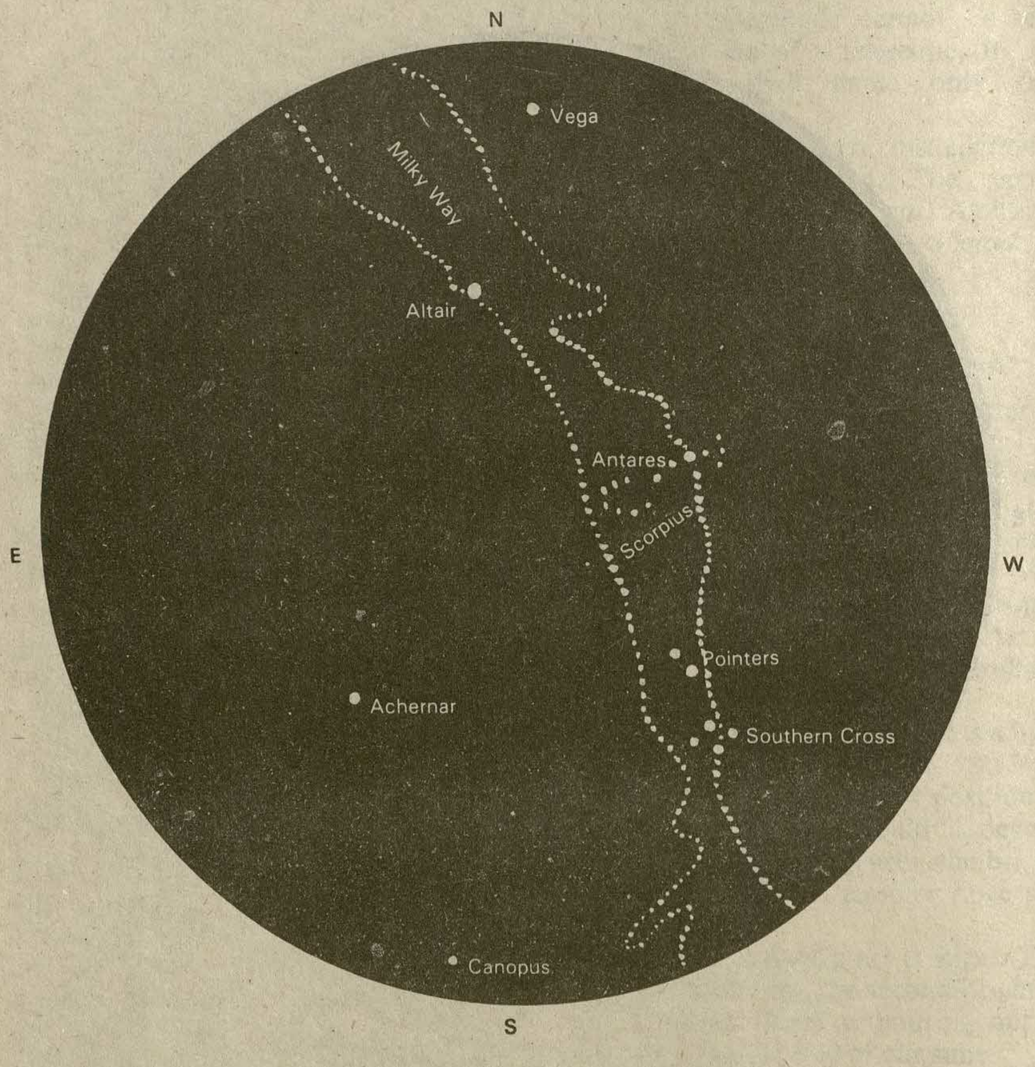


Figure 10.9: The evening sky in spring — about 8.30 p.m., mid-September. When facing south hold the chart so that "S" is at the bottom, and so on.

EXPERIMENT 10.1

Identifying some constellations and some bright stars

Each group will need:

- three empty fruit tins
- hammer and sharp nail
- tissue paper

What to do

- Select three empty fruit tins.
- Trace the patterns of the three constellations shown in figure 10.10 on tissue paper.
- Transfer each of these patterns to the bottom of a tin.
- Using a sharp nail, punch holes in the bottom of each tin corresponding to the pattern of each constellation.

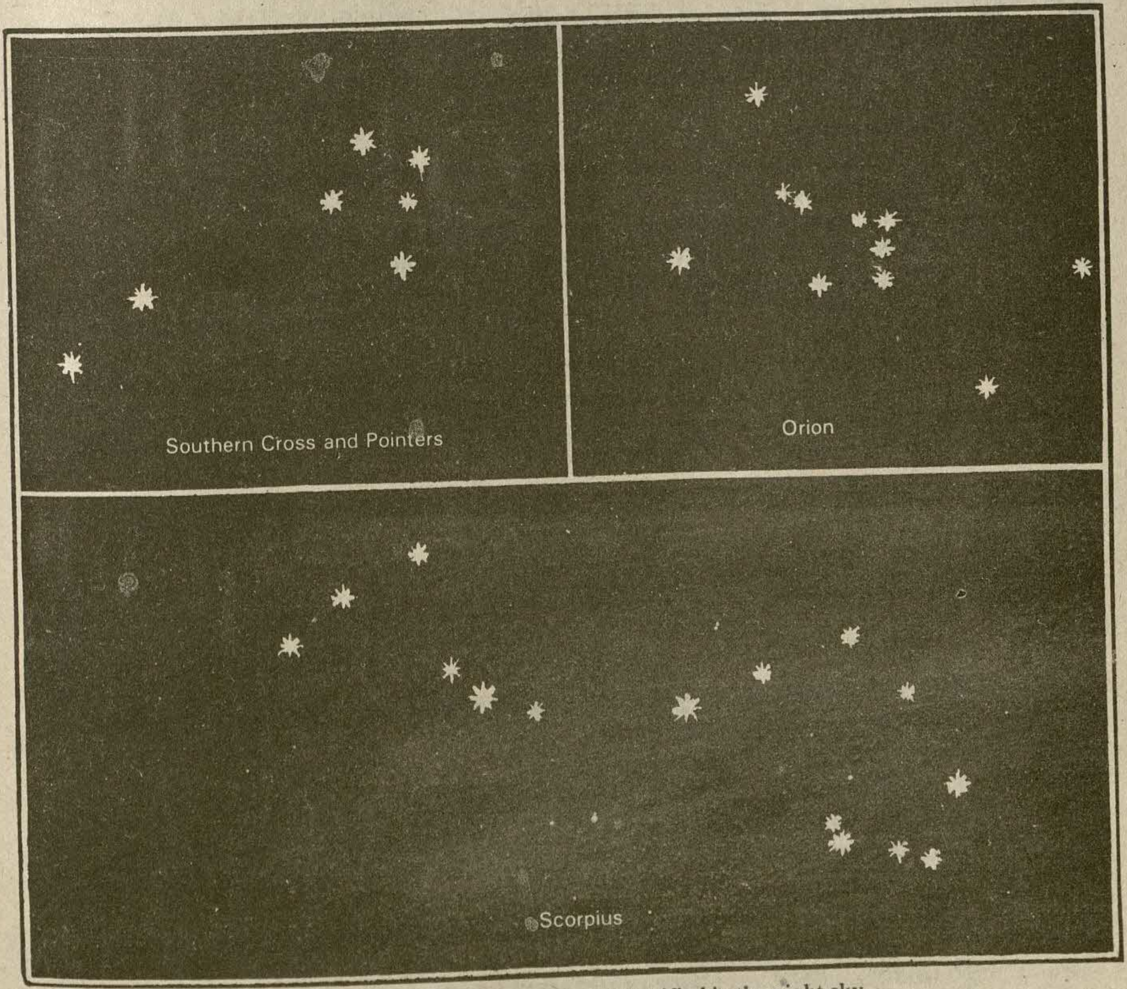


Figure 10.10: Three constellations easily identified in the night sky.

- Place a lighted torch in each tin in turn and hold the tin above you. Use these tins to identify the constellations in the sky.
  - Orion is in the east early in the evening in December, almost overhead early in the evening in February and towards the west in April.
  - The Cross is in the south in summer and almost overhead and reversed in winter.
  - Scorpius is towards the east early in the evening in April. It is almost overhead in the early evening in late June and towards the west in August.

EXPERIMENT

10.2

Photographing star trails in colour

Each group will need:

- camera — preferably 35 mm reflex
- stand for camera
- high-speed Ektachrome film

What to do

- Choose a position well away from street lights, house lights and city skyline glare.
- Choose a clear moonless night, preferably without any wind.
- Place the camera on a firm box or, better still, use a tripod.
- Point the camera towards the east just above the horizon.
- Set the lens of the camera at infinity and open the aperture for 45 minutes.
- Take other pictures in various directions. (Remember that dew on the lens may be a problem if the camera is pointed upwards.)
- If you are interested in photographing constellations, the exposure time should be about 30 seconds.

Stars

1. The visible stars are huge masses of very hot material at enormous distances from the earth.
2. The sun is the nearest star.
3. Stars are most plentiful in the Milky Way.
4. Stars, like the sun, move across the sky in an east–west direction.
5. Stars may be coloured. The colour of a star depends on its temperature.
6. Many stars have been grouped for identification. Such groups are called constellations.

Spelling list

alpha
Antares
astrology
astronomy
beta
Betelgeuse
Centaurus
constellation
horizon
identify
lens
Orion
photography
Scorpius
Sirius
telescope
trail

Things to do

10.1 From a high spot overlooking a roadway, take a photograph of night traffic (exposure time 1 second).

10.2 Make a sighting tube, using a cardboard tube from the kitchen. Support it with Sellotape wound in a figure 8 around a garden stake pushed into the ground. Sight a star low down on the eastern horizon. Come back in 10 minutes to find out how much and in what direction the star has moved. Use the tube to sight other stars in other parts of the sky.

10.3 Carry out an experiment to help you understand the theory that the colour of a star depends on its temperature. Connect a 12 volt lamp to a 12 volt power pack. Vary the voltage gradually from 2 up to 12 volts. Feel the globe at each voltage. Tabulate your results.

Voltage	Colour of globe	Feel of globe

More questions

10.4 Gemini (the Twins) is a constellation near Orion. It contains two bright stars, Castor and Pollux. What is the legend about the naming of these two stars?

10.5 What is a falling star? How big is it and how far away is it, as a rule?

10.6 What is the furthest distance out from the earth a spacecraft has travelled? How much further would it need to travel to reach the second-closest star, Proxima Centauri, 50 000 000 000 000 kilometres away?

10.7 We are on a planet revolving around a star — the sun. Do you think there may be other planets out in space revolving around other stars? Could there be some form of life on some of these other planets?

Test yourself (chapter 10)

Pick the best answer to each question and write its letter in your workbook.

1. Which of the following is a constellation:
   (a) Alpha Centauri
   (b) Centaurus
   (c) Betelgeuse
   (d) Canopus?
2. Which of the following is a star:
   (a) Orion
   (b) Sirius
   (c) Centaurus
   (d) Scorpius?
3. A light year is:
   (a) 365 days of sunlight
   (b) the distance to Proxima Centauri
   (c) the distance a star travels in a year
   (d) none of the above.
4. A star rising in the east would set:
   (a) in the north
   (b) in the south
   (c) in the east
   (d) in the west.
5. The hottest stars in the sky are:
   (a) red
   (b) white
   (c) blue
   (d) yellow.

11

The solar system

Figure 11.1 is a diagram of the solar system. Such a diagram is sometimes called a model because it has been built to explain all the information that has been collected about the solar system. All this information is the result of countless hours of work by many people. We believe that this model is correct.

In the past, however, there have been other models and these were thought to be correct at the time. Most people who lived 1800 years ago at the time of Ptolemy, for example, thought his model was correct because it explained everything they knew about the solar system at that time. Ptolemy's model had the sun moving around the earth! (See figure 11.2.)

Figure 11.3 shows some more information we have about the solar system — the relative sizes of the planets and the sun.

The orbits of the planets

The paths of the planets around the sun are approximately circles or, more accurately, ellipses. (See figure 11.4, page 115.)

This was first calculated by the German astronomer Johannes Kepler early in the seventeenth century. He used information obtained from the observations of Tycho Brahe (1546–1601). These two men worked before the invention of the telescope.

The speeds at which the planets move depend on their distances from the sun. Mercury has the greatest speed and Pluto the smallest.

Table 11.1: Speeds of planets

Planet	Speed through space
Mercury	175 000 km/h
Earth	107 000 km/h
Pluto	18 000 km/h

Many of our ideas about distant planets are based on very little direct observation. Knowledge of closer planets and satellites, however, often helps in explaining things about more distant planets. A satellite is a heavenly body revolving about another heavenly body. For example, the moon is a satellite of the earth. Because it is the closest object to us, astronomers have been able to study the moon in detail. Much of the information obtained about the moon has been used when making up theories about the rest of the solar system.

The moon

The moon is one of the largest satellites in the solar system. It is so large that some scientists prefer to call the moon and the earth twin planets. It revolves around the earth west to east once in every 27.3 days. **This revolution is in the same direction as the earth's rotation.**

Because of these two motions, each time the moon rises it is about an hour later than the day before; the earth has to rotate a little further each day to get into the same position with respect to the moon.

One remarkable thing about the moon is the way it always shows us the same face. Some scientists explain this by suggesting that the moon is slightly irregular, having one side heavier than the other, and that it is the heavier side that is kept constantly directed towards us as though it were a plumb bob.

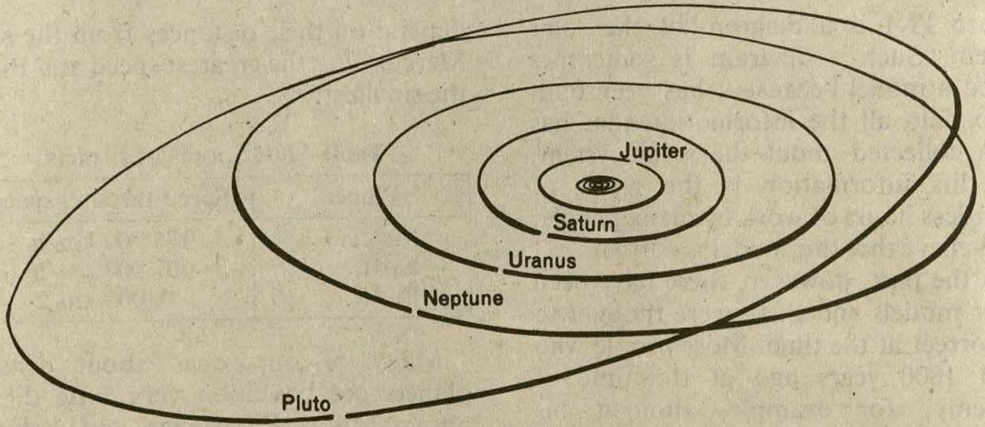
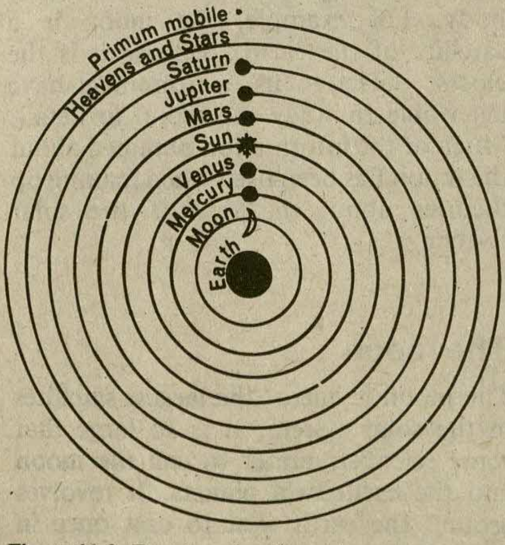


Figure 11.1: The solar system as present-day astronomers believe it to be. This diagram has the appearance of a huge wheel with only Pluto out of place.



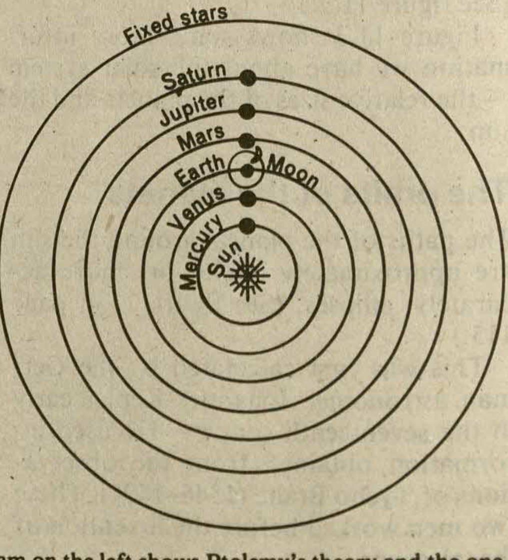


Figure 11.2: Two theories about the universe. The diagram on the left shows Ptolemy's theory and the one on the right shows the theory put forward by Copernicus.

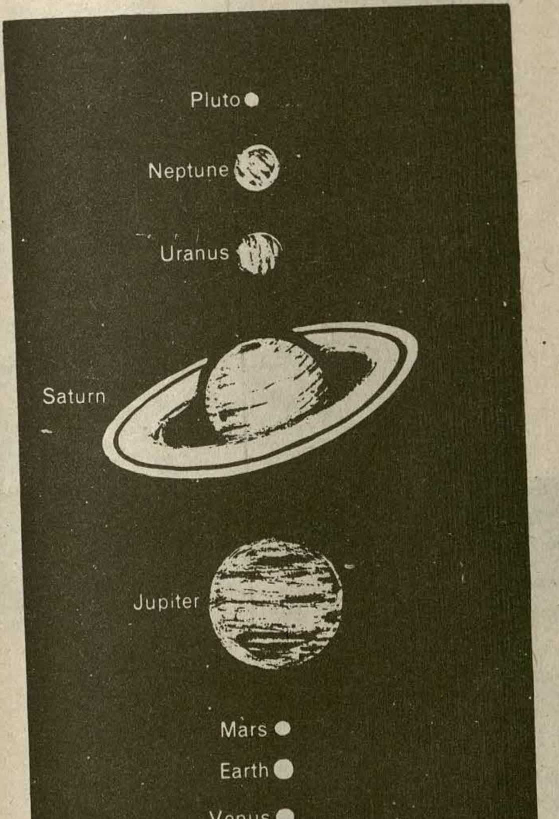


Figure 11.3: The relative sizes of the planets compared with the sun.

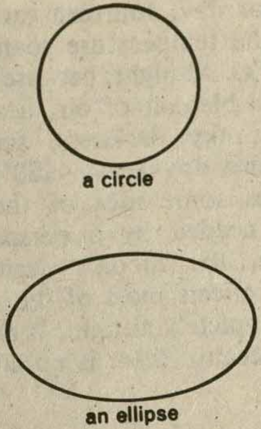


Figure 11.4: The paths of the planets in the solar system are ellipses.

The diameter of the moon is one-quarter of that of the earth but its weight is only about one-hundredth of the earth's weight. Because of this, an object if weighed on the moon would register only one-sixth of its weight on earth. This is also the explanation of the moon's lack of an atmosphere. Gravity on the moon is not strong enough to prevent the fast-moving molecules of gases from escaping into space.

The moon's surface. Without an atmosphere the moon can have no climate. It has neither wind nor rain. For this reason, rocks on the moon's surface must be the same as they were when the moon was formed 4000 million years ago.

Scientists now have samples of rocks brought back from the moon by lunar expeditions in the early 1970s. These samples have provided valuable information, not only about the structure of the moon, but also about the universe itself.

For people landing on the moon, the surface can be very dangerous. Without a shielding atmosphere there is no protection against either radiation or particles coming from space. During the long lunar day, fourteen earth days in length, the temperature soars to more than 100°C. At night, because there is no protective blanket of air, heat radiates into the inky darkness, sending the temperature down to −180°C. Figure 11.5 gives some idea of the type of clothing needed by a person moving about on the moon's surface. This clothing reflects most of the sun's rays and is completely airtight. It needs to be airtight because there is no atmosphere on the moon.

Much of the moon's surface is covered with dust, the result of a constant shower of very small stones called meteorites. Very occasionally much larger meteorites must have crashed on to the moon. Scientists believe that these crashes are the cause of the many craters seen on the moon's surface. (See figure 11.6.)

One very good reason for this belief is the existence of similar craters on the earth's surface. (See figure 11.7.)

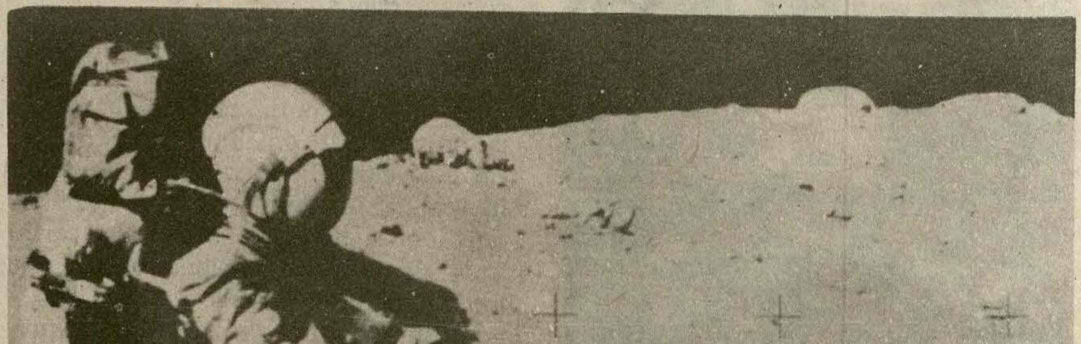


Figure 11.5: An astronaut gathering dust and rock samples on the moon. Notice his special clothing. It is designed to reflect the intense heat from the sun and to enable the man to survive in a vacuum. (Photo courtesy NASA)

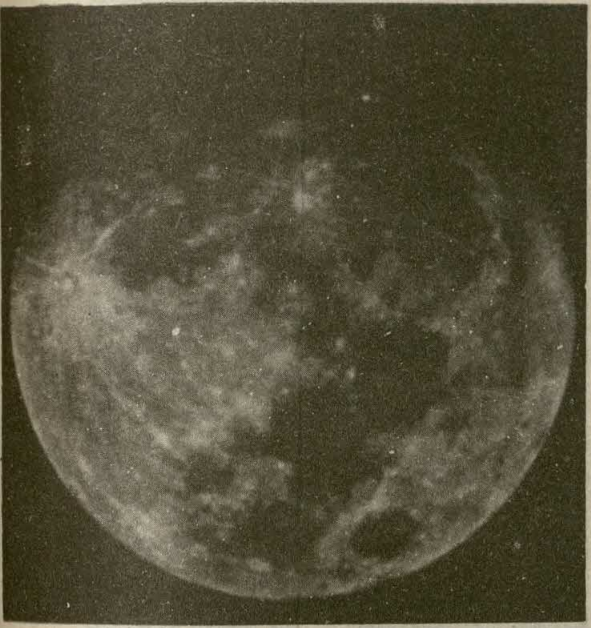


Figure 11.6: A photograph of the moon taken through a school telescope. A standard reflex camera was used and was attached to the eyepiece tube. Both the lens of the camera and the eyepiece were removed. Exposure 1/50 second at *f* 10. Notice the radiating lines from the crater on the left. These lines are thought to have been caused by a huge meteorite spattering material when it struck the moon's surface.

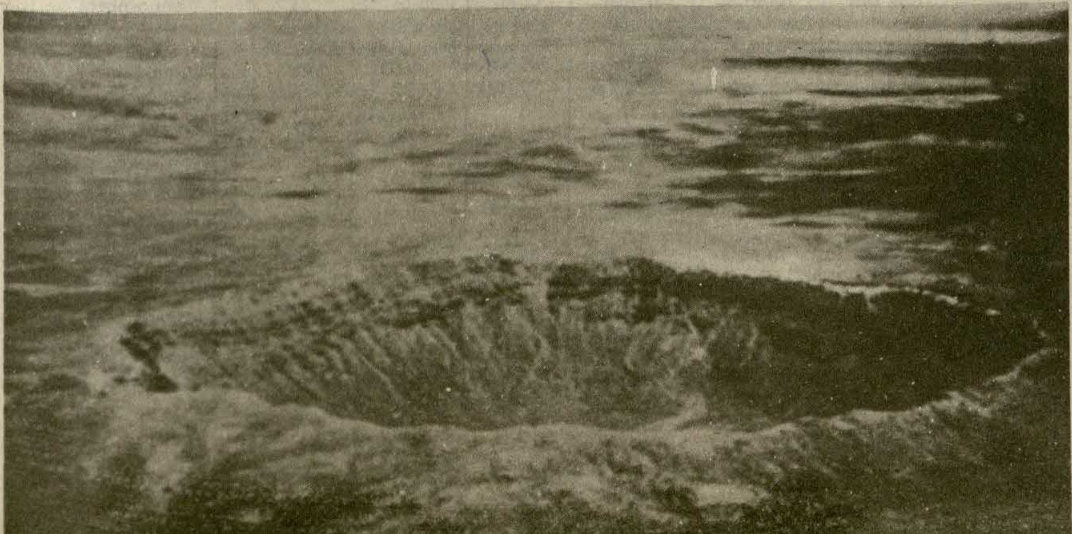
Venus

Venus is the third-brightest object in the sky: only the sun and the moon are brighter. It is about the same size as the earth. Being the second-innermost planet of the solar system, it is never seen far from the sun in the sky; it rises and sets near the sun each day. For the same reason it is seen either as the Morning "Star" or the Evening "Star". It also shows phases like the moon. (See figure 11.8, page 118.)

Venus is always covered with clouds. These consist of fine crystals of ice that reflect about 70 per cent of the sunlight back into space. This is the reason for the dazzling appearance of Venus in the sky.

***The mystery of Venus*.** Until a few years ago the surface of Venus was a mystery. In recent years radio astronomy has helped to solve this mystery. Venus radiates energy that can be picked up by special radio receivers. Astronomers can tell that this energy must be coming from a red-hot surface. The idea that the surface of Venus is red-hot was verified by

Figure 11.7: A crater in Arizona, U.S.A. There is no evidence here of any volcanic action. The crater must have been caused by a recent meteorite — no more than 20 000 years ago. (Photo courtesy John Wiley and Sons, Inc.)



the spacecraft Mariner II in 1962.

Have you noticed that a cloudy night in summer is often much hotter than a clear night? This is the explanation of the high temperature on Venus; the heat is trapped beneath the perpetual blanket of clouds.

The atmosphere on Venus is thought to consist of carbon dioxide and water vapour and is thirty times as dense as the earth's atmosphere.

Astronomers have found that Venus, like the earth, rotates. This discovery was made in spite of the clouds that always cover the planet. Radio signals were transmitted as a beam towards Venus. The astronomers knew the signals would be reflected back to earth. Analysis of the reflected signals showed that Venus is rotating. However, it rotates very slowly compared with the earth. As table 11.2 shows, one rotation takes 250 earth days.

It is most unlikely that Venus supports life even in its simplest forms. If calculations about the planet's temperature are correct, it is hardly likely that any organisms could survive on it.

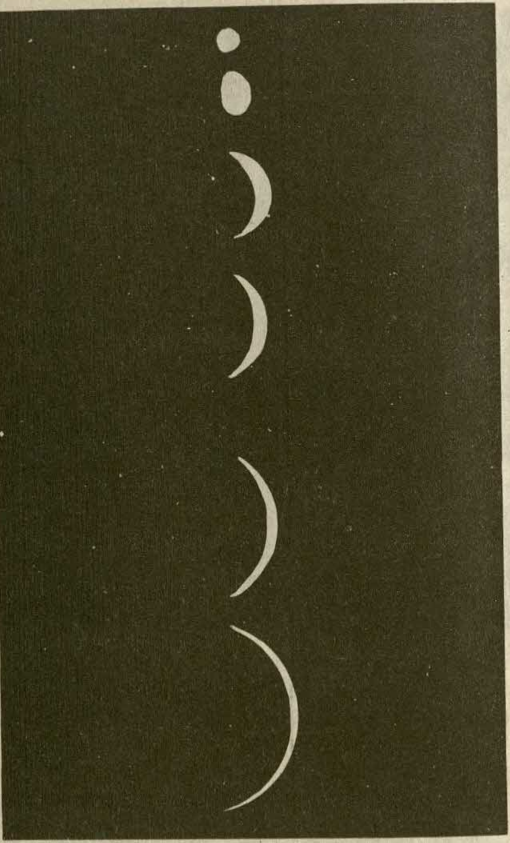


Figure 11.8: The phases of Venus. Venus appears full when on the far side of the sun. It appears as a thin crescent when almost between us and the sun.

Table 11.2: The planets

Planet	Average distance from sun (kilometres)	Time for one rotation (earth units)	Length of year (earth units)	Diameter (kilometres)	Weight (compared to earth)	Number of moons	Atmosphere
Mercury	57 000 000	60 days	88 days	4 800	0.05	none	carbon dioxide
Venus	107 000 000	250 days	225 days	12 000	0.8	none	carbon dioxide, nitrogen, water
Earth	150 000 000	24 hours	365 days	12 800	1.0	1	nitrogen, oxygen, water, carbon dioxide, argon
Mars	227 000 000	25 hours	687 days	6 400	0.1	2	carbon dioxide, nitrogen, water
Jupiter	780 000 000	10 hours	12 years	144 000	320	12	hydrogen, helium, methane, ammonia
Saturn	1 427 000 000	10 hours	30 years	120 000	95	9	same as Jupiter
Uranus	2 900 000 000	11 hours	84 years	48 000	15	5	same as Jupiter
Neptune	4 500 000 000	15 hours	165 years	45 000	17	2	same as Jupiter
Pluto	6 000 000 000	6 days	250 years	5 800	0.8	none	unknown

Mars

Mars is perhaps the most interesting planet (besides our own) in the solar system. Its diameter is only about half that of earth's and it revolves around the sun once in approximately two earth years. At times the earth and Mars are on the same side of the sun and are less than 56 million kilometres apart. At these times Mars appears brightest and is in the best position for observation. The next time that this will occur is September 1988.

The colour of Mars. Mars is a reddish-orange colour. One theory is that this colour is due to iron oxides. Scientists think that the planet has a large amount of iron in its crust and that this iron has combined with oxygen to form iron oxides. This is also an explanation of the present lack of oxygen in the Martian atmosphere.

The atmosphere. The atmosphere on Mars is mainly carbon dioxide and nitrogen with a little water vapour. The total pressure of these gases on the surface of the planet is less than ten grams per square centimetre. When we remember that the pressure of the earth's atmosphere is one thousand grams per square centimetre, we realize how thin is the Martian air.

When Mars is examined through a telescope, dazzling white caps can be seen at the poles. These can be only thin layers of frost, because there is very little water vapour in the atmosphere.

The canals on Mars. Towards the end of the last century some observers saw dark lines on the face of Mars. These were thought to be canals and the idea developed that Mars was populated by highly intelligent beings who had cut canals so that water could be brought from the poles to the arid regions near the equator. This theory is no longer accepted.

The spacecraft landings on Mars in 1978 have shown that there is no life on the surface of the planet. It is highly unlikely that there is any life beneath the surface.

The landings have also provided some clues to the origin of the so-called canals. Some of these at least are probably channels caused by floods of water blown up from beneath the surface in past volcanic eruptions. This water has since soaked deep into the dust and rock covering the planet's surface.

Jupiter

Jupiter is the giant of the solar system. It has twice as much matter as all the eight other planets put together. This matter, however, is mainly hydrogen and helium, the two lightest elements in the universe.

Because of its great size, the pressure at the centre of Jupiter is tremendous. It is great enough to compress the hydrogen and helium into solids. The atmosphere of Jupiter has almost the same composition as its core; it is made up of hydrogen and helium with some ammonia and methane. The planet has no surface. What could correspond to a surface is probably a frothy mixture of gas and liquid.

Jupiter is enveloped in clouds of frozen ammonia and methane. Beneath these clouds violent electric storms are raging continuously.

Although it appears such an inhospitable place, scientists do not completely discount the possibility of some sort of life on the planet; but it is difficult to understand at present how the question can ever be resolved.

For the radio astronomer, Jupiter is

one of the most fascinating objects in the universe. It is like a vast broadcasting station transmitting energy on many different wavelengths. Scientists have not yet been able to offer a satisfactory explanation for all these kinds of radiations.

Mercury

Because it is so close to the sun, Mercury is a difficult planet to observe. It is in the day sky and for this reason it is only possible to glimpse it near sunrise and sunset.

Saturn

Saturn is perhaps the most interesting planet to look at through a telescope. (See figure 11.9.) It has nine moons and is surrounded by three flat rings that probably consist of dust and ice crystals.

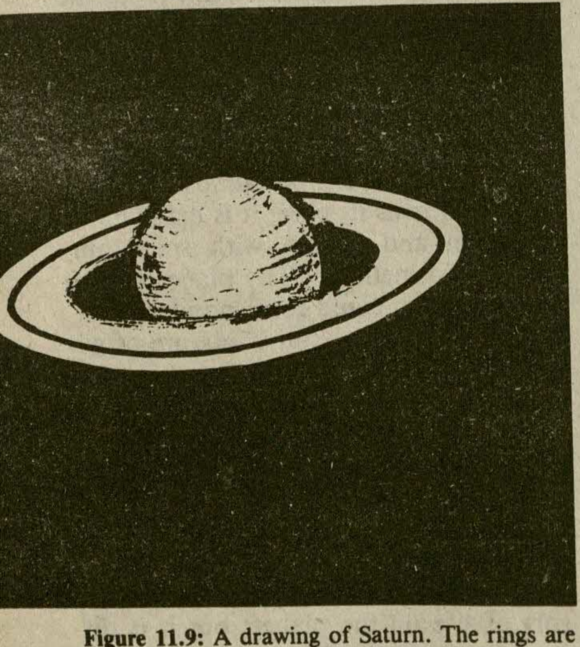


Figure 11.9: A drawing of Saturn. The rings are thought to be made up of small crystals of ice. These rings rotate at different speeds, the closest ring rotating most rapidly.

Saturn is the second largest of the planets, having a diameter almost ten times that of the earth. It is so far away from the sun that it is very cold — much colder than Jupiter. It takes almost 30 years to travel around the sun.

Uranus and Neptune

These two planets are very difficult to observe. This is because of their great distances from the earth. Both are thought to be Jupiter-like planets, composed mainly of hydrogen and helium.

Pluto

Very little is known about Pluto. It is one of the smallest planets in the solar system and is so far out in space that a very good telescope is needed to pick it up.

Pluto is five light hours away from earth. This means that if a huge flash of light occurred on Pluto, five hours would elapse before the flash would be picked up in telescopes on earth.

Other objects in the solar system

Asteroids. Between the orbits of Mars and Jupiter there are thousands of small objects called asteroids. They range in size from small rocks to planets much smaller than our moon. It is thought that the asteroids are the remains of a tenth planet, now broken up. Some of the larger asteroids have been named, for example, Pallas and Vesta.

Meteors. These are the ''falling stars'' or ''shooting stars'' seen on a clear night. They are small fragments of matter attracted to the earth as it journeys through space. Most meteors are quite small, usually a millimetre or so in diameter. In space they are invisible, but

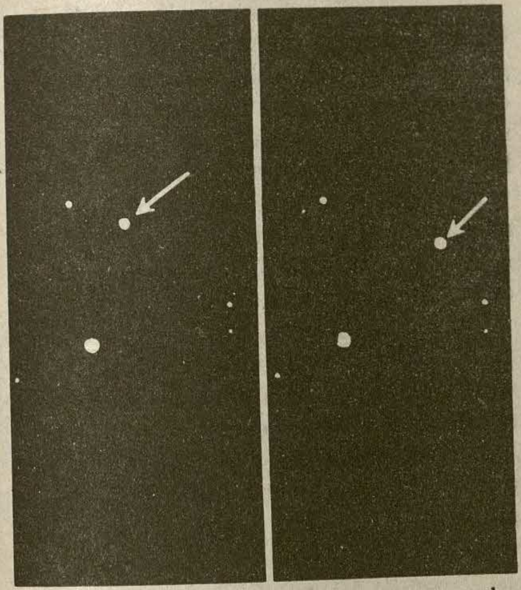


Figure 11.10: Pluto, the latest planet to be discovered. This was in 1930. The two photos, which were taken a day apart, show the planet moving against the background of the distant stars.

as they come into the earth's atmosphere they become white-hot owing to friction with the air, and they flash across the sky as streaks of light. They vaporize before they reach the earth's surface.

Meteorites. These are much larger objects than are "shooting stars". They range from small stones to huge objects such as the one that caused the hole shown in figure 11.7.

Comets. These are objects that travel around the sun in very elongated orbits. Comets are made up of dust and gas; in shape they have a head and tail. They become luminous as they approach the sun, and the tail always points away from the sun. (See figure 11.11.)

A comet is almost invisible until it approaches the sun and becomes heated. This is the cause of the sudden appearance of comets in the sky. In early times people viewed the appearance of comets with awe and regarded them as omens of impending disaster.

One of the best known comets is *Halley's Comet*. It appeared in 1682, 1759, 1835 and 1910. Astronomers predict the next appearance in 1985.

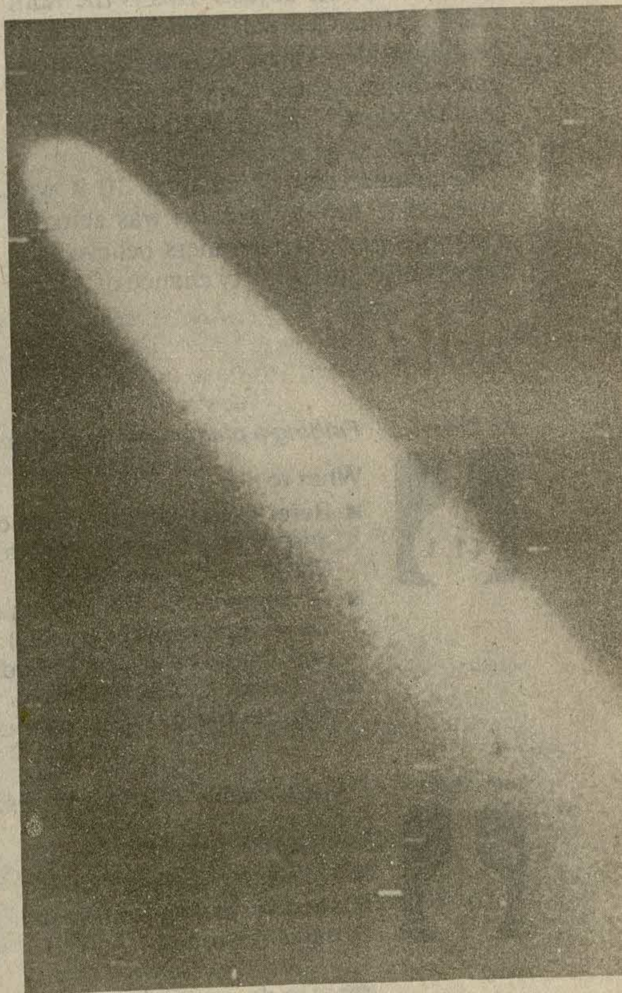


Figure 11.11: A comet seen in the northern hemisphere in November 1948. The photograph was taken through a telescope geared to follow the movement of the comet across the sky. As a result the stars in the background appear as strips of light instead of small circles. (Photo courtesy *Courier-Mail*)

Beyond the solar system

If we journey from the sun outwards at the speed of light (300 000 kilometres per second), it will take us five hours to reach Pluto. Once we say goodbye to Pluto we have a lonely and monotonous journey of 4¼ years before we can reach the next known object. This is the faint star Proxima Centauri, which appears to be alongside Alpha Centauri. Astronomers believe there is a fifty-fifty chance that Proxima Centauri will, like the sun, have a family of planets.

Remember that in chapter 10 it was stated that Alpha Centauri was actually a double star. Astronomers believe that there is also a fifty-fifty chance of Alpha Centauri having planets. They even suggest that it is only by chance that our own solar system does not have two stars. Jupiter is made of helium and hydrogen like the sun. Perhaps if Jupiter were bigger and therefore exerted greater pressures at its core, it too would generate sufficient heat to cause it to emit light and become a star.

Our solar system, therefore, is only one of what could be millions of other such systems in the universe. Our system contains at least one planet supporting life. One wonders how many other planets there are in the universe also supporting life; and more interesting still—what forms does this life take?

EXPERIMENT 11.1

Finding a planet among the stars.

What to do

- Refer to the weather notes of the daily newspaper to find the time of rising and setting of some planets. Planets that are fairly easy to find are Venus, Mars, Jupiter and Saturn.
- Remember that the planets rise in the east (approximately) and set in the west (again approximately). Venus and Jupiter are the brightest planets and should be easiest to find.
- If Jupiter is visible and you have a telescope or pair of binoculars, try to pick out one or two of its moons

EXPERIMENT 11.2

Using a model to explain the phases of the moon

Each group will need:

- tennis or golf ball
- electric reading lamp or slide projector
- darkened room

What to do

- Set up a slide projector or a reading lamp with the shade removed in a darkened room. The lamp is the "sun".
- Hold a tennis ball in the direct rays of the lamp. Notice that one half of the "moon" is illuminated, while the other half is in darkness.
- Slowly turn round while you hold the ball at arm's length – refer to figure 11.12. Your head now represents the earth.

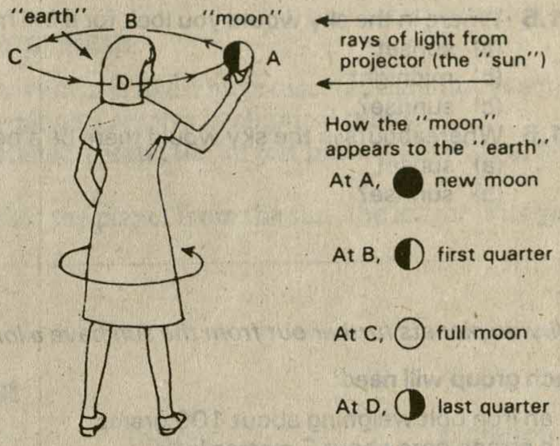


Figure 11.12: Using a model to demonstrate the phases of the moon.

Questions

11.1 How are the sun, moon and earth placed when you see all of the illuminated half of the moon, that is, a full moon?

11.2 What are the relative positions when you see only the darkened side of the moon or a thin crescent of lighted surface?

11.3 What are the relative positions for the four phases of the moon — new moon, first quarter, full moon and last quarter?

EXPERIMENT

11.3

Recording, over a period of one month, the phases of the moon and its times of rising and setting

What to do

- Begin your observations with a full moon.
- Record the time of rising of the moon in the east and its time of setting in the west. Metropolitan daily newspapers provide this information.
- At the same time draw the shape of the moon. This can be done by observing the moon at a suitable time during the day.
- Repeat these observations at weekly intervals covering a period of one month.

Time in days	Appearance of moon	Time of rising	Time of setting
0	(full moon)		
7			
14			
21			
28			

Questions

11.4 Why do we see only a thin crescent of the moon at one time and a full face of the moon at a later time?

11.5 Where in the sky would you look for a full moon at:
  (a) sunset
  (b) midnight
  (c) sunrise?

11.6 Whereabouts in the sky would there be a new moon at:
  (a) sunset
  (b) sunrise?

EXPERIMENT 11.4

Why do planets further out from the sun have a longer "year"?

Each group will need:

- an iron bolt weighing about 100 grams
- a strong cord about 5 metres long
- stopwatch

What to do

- Tie a bolt that weighs about one hundred grams to a strong cord about five metres long.
- Work with two other people, one to act as a timekeeper and the other as a revolution counter.
- Whirl the bolt above your head in an almost horizontal circle with a radius of two metres and count the number of revolutions in ten seconds.
- Repeat using radii of three metres and four metres. It is best to begin with a short cord and increase the radius by allowing the cord to slip out through your fingers as you whirl it around your head.
- Make sure that the cord is nearly horizontal during the movement. You will find that the shorter the cord the greater the pull on your fingers.
- Record your results as follows:

Radius (approx.)	Orbit (approx.)	No. of revolutions		Speed of bolt (approx.)
		In 10 seconds	In 1 second	
2 m	12 m			
3 m	18 m			
4 m	24 m			

Questions

11.7 In which case was the orbit longest?

11.8 In which case did the bolt travel with the greatest speed?

The solar system

1. The solar system is like a huge disc, ten light hours across.
2. The nine planets revolve in elliptical orbits.
3. All the planets rotate; the largest planets have the most rapid rotation.
4. The further the planet from the sun, the longer is its year.

Spelling list

asteroid
comet
crater
ellipse
Jupiter
Mars
Mercury
meteor
meteorite
Neptune
phases
planet
Pluto
revolve
revolution
rotation
Saturn
southern
system
Venus

Things to do

11.9 Make arrangements to visit an observatory or the home of an amateur astronomer. Ask to be shown the moon and those planets in the night sky at the time. Ask also to be shown a double star.

11.10 Visit a museum with a planetarium. Perhaps the same museum will have some meteorites on display. What is the difference between a meteor and a meteorite?

11.11 Locate one of the planets in the night sky. Make a sketch map showing its position in relation to some nearby stars. Find the same planet a week later at the same time of night. Plot its position on your original sketch map. Repeat this observation at weekly intervals for a month. Can you now understand why early astronomers called the planets "wandering stars"?

More questions

11.12 List two ways in which you can distinguish a planet from a star.

11.13 What are some of the theories explaining the origin of the moon? Have any of these theories been abandoned since men have landed on the moon?

11.14 "We see the sun for a few minutes after it has set." Is this statement true? Calculate how long it takes light to travel from the sun to earth.

11.15 What are some of the problems of travelling through space and landing on the moon? Use your library to find out about:
- (a) the type of clothing used
- (b) the kind of food carried
- (c) how waste is disposed of
- (d) problems of weightlessness
- (e) the kind of activities that are carried out in space.

11.16 Would a space traveller standing on the moon's surface see meteors? If not, why not?

11.17 At the time when satellites were first placed in orbit, many people thought they were a waste of money. What are some of the benefits of satellites?

11.18 Where in the sky does the moon appear when it is new?

11.19 Why does the sun appear to us on earth to be no bigger than the moon?

11.20 What planet or satellite, apart from the earth, would be most interesting to each of the following scientists:
- (a) a geologist
- (b) a radio astronomer
- (c) a biologist
- (d) a botanist
- (e) an astronomer?

Test yourself (chapter 11)

Write the answers to the following in your workbook.

1. Name the following:
   - (a) the largest planet
   - (b) the smallest planet
   - (c) the coldest planet
   - (d) the planet with the greatest number of satellites
   - (e) the planet made up of the lightest materials
   - (f) the planet with the shortest day
   - (g) the planet with the longest day
   - (h) the planet with the shortest year.

In answering questions 2 to 5, choose the best answer for each question and write its letter in your workbook.

2. Which of the following statements is correct? Planets:
   - (a) are brighter than star
   - (b) appear to wander against the background of the stars
   - (c) are never seen during daytime
   - (d) are generally larger than stars.

3. A new moon may be seen in the west at:
   - (a) sunrise
   - (b) sunset
   - (c) midday
   - (d) midnight.
4. Venus shows distinct phases like the moon because:
   - (a) it is smaller than the earth
   - (b) it is closer to the sun than the earth is
   - (c) it is the brightest planet in the sky
   - (d) it rotates on its axis much more slowly than the earth does.
5. The planet moving fastest through space is:
   - (a) Jupiter
   - (b) Pluto
   - (c) Mercury
   - (d) Saturn.

12

Water

Water, more than any other substance, determines the distribution of life on earth. Deserts have relatively little life because there is insufficient water, while tropical rainforests are teeming with life.

Living matter is mainly water. The human body is about 70 per cent water and a jellyfish is 99 per cent water.

Water in the oceans covers three-quarters of the earth's surface, and there is enough held in the polar icecaps to drown most of the cities of the world if the ice melted.

Water as a solvent

Many substances dissolve in water. Sugar, salt, bicarbonate of soda, vinegar and carbon dioxide gas are all soluble in water. The oceans contain many different substances in solution, most of them washed down out of rock and soil by the creeks and rivers.

However, there are also many substances that do not dissolve in water, such as oils and fats, wood, cloth, plastics, concrete, most metals and all those other materials that we see around us day after day in spite of continued exposure to rain. Experiment 12.3 tests the solubility of some common substances in water.

Air dissolved in tap-water

Tap-water and sea water contain dissolved air. This may be shown by boiling some water in the apparatus sketched in figure 12.3.

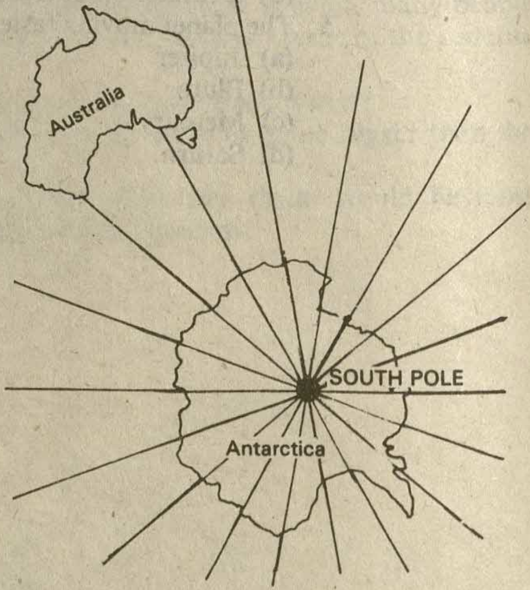


Figure 12.1: This map shows that Antarctica has twice the area of Australia. Antarctica is covered by an ice cap up to five kilometres thick. Try to imagine what an enormous amount of water this is — think of it as a huge, frozen dam.

Care must be taken to see that the flask and delivery tube are completely full of water before boiling. Any steam given off condenses when it meets the dish of cold water. Therefore the gas collected in the top of the tube must be something other than steam. If enough of this gas is obtained it may be tested to see whether it supports burning. It will

Figure 12.2: A field camp on the Antarctic ice, near Mawson. In places the ice is eight kilometres thick. If it all melted, enough water would flow into the oceans to drown most of the world's coastal cities. (Photo by A. Vrana, courtesy Antarctic Division of the Department of Science)

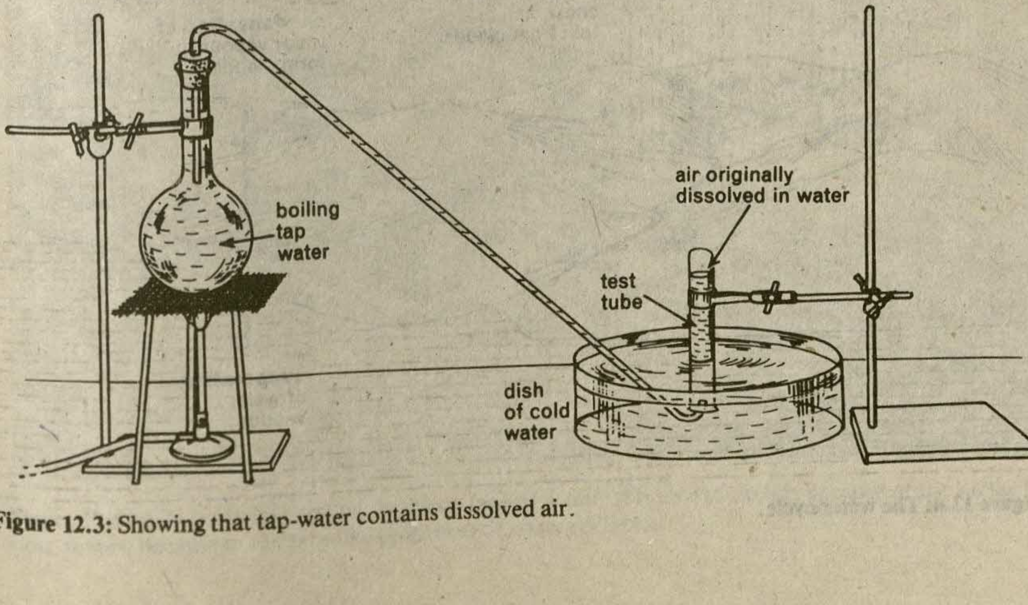


Figure 12.3: Showing that tap-water contains dissolved air.

be found that it does this in much the same way as air does, leaving behind about four-fifths of its volume when the flame is extinguished. We can therefore conclude that tap-water contains dissolved air.

City water supply authorities deliberately aerate town water to make it more pleasant to taste and to help oxidize some impurities. The creeks, rivers and oceans could not support the life they contain without dissolved air.

The water cycle

The cycle of water is shown in figure 12.4.

Water is evaporated from oceans and lakes, from moist soil and from living things. Some of this water vapour eventually forms clouds. When clouds have been formed and conditions are right, rain, hail or snow may fall. Water from these different forms of precipitation runs down into soil, creeks and rivers, lakes and the oceans, and the cycle is complete. The source of energy for this cycle is the sun.

The behaviour of water on freezing

How often have you had a bottle of soft drink burst when left in the freezing compartment of a refrigerator? This happens because water expands on freezing. This expansion may be a problem to householders in cold climates unless water pipes are protected from the cold. If the water in the pipe freezes, the pipe may burst.

Because water expands when it changes into ice, ice is lighter than water and therefore floats. This expansion has a very important effect on the oceans of the world. It means that, as ice forms, it remains on the surface. If ice sank it is likely that most of the oceans of the world would be frozen from the bottom nearly to the top. This would completely

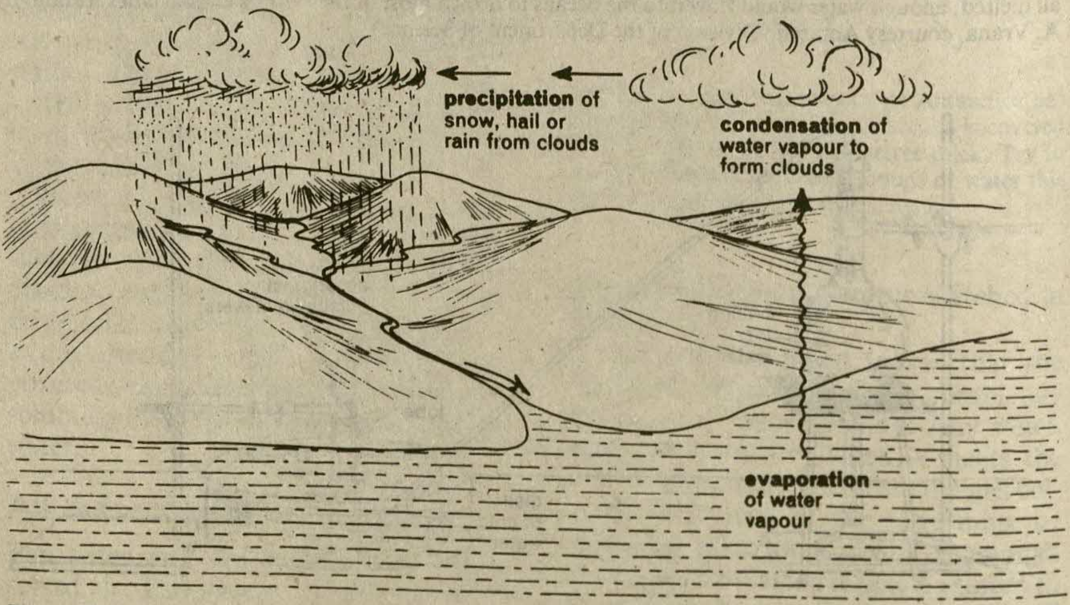

precipitation of snow, hail or rain from clouds
condensation of water vapour to form clouds
evaporation of water vapour

Figure 12.4: The water cycle.

alter the distribution of life in the sea and would have a marked effect on the currents and climate of the world.

Surface tension of water

Many insects, such as water striders, can move over the surface of water without becoming wet. (See figure 12.5.) A razor blade, if placed carefully on the surface, will float on water. These observations indicate that water behaves as though it has a thin tight skin over it. This behaviour is due to the *surface tension* of the water.

The surface tension of water prevents it from wetting your greasy hands when you try to wash them under a tap. The addition of soap or detergent reduces the surface tension and the water wets the skin. A few drops of detergent near the razor blade will cause it to become wet and sink.

Hardness in water

Hard water contains substances that react with soap to form a greasy scum. This prevents the soap from acting to reduce the surface tension of the water. Many detergents are just as effective in hard water as in soft water; they do not react with the substances that make the water hard. (See experiment 12.5.)

Tests for water

Suppose we are handed a sample of a clear colourless liquid and are asked to identify it as water.

One test would be to cool it and check the temperature at which it solidified. Pure water changes to ice at 0°C.

Another test would be to check its boiling point; pure water boils at 100°C when the pressure on it will support a column of mercury 76 cm high.

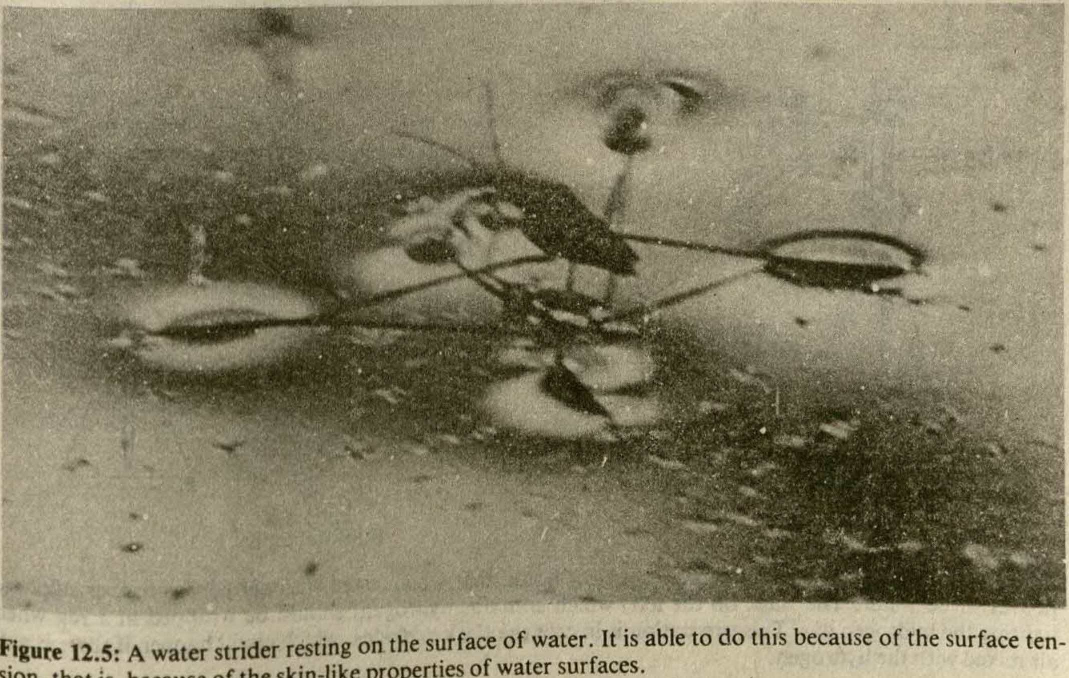


Figure 12.5: A water strider resting on the surface of water. It is able to do this because of the surface tension, that is, because of the skin-like properties of water surfaces.

Neither of these tests could be used if we had only one drop of the liquid. What test could be applied that would require only one drop of the liquid to establish whether or not it was water? Anhydrous copper sulphate can be used for such a test. A sample may be prepared by heating some copper sulphate in a test tube. When copper sulphate crystals are heated, as in figure 12.6, it is noticed that drops of liquid drip from the end of the tube and the crystals break up and change from blue to white. Water is the only substance that, when added to the white powder, will turn it blue again. The white powder is called anhydrous copper sulphate and it is used to test for water.

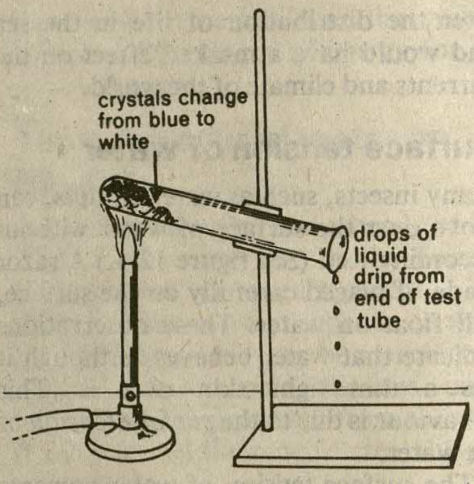

crystals change from blue to white
drops of liquid drip from end of test tube

Figure 12.6: Heating crystals of copper sulphate.

The synthesis of water

The apparatus shown in figure 12.7 is used to synthesize water, that is, to form water from its elements.

Hydrogen is prepared by pouring dilute hydrochloric acid on some zinc in the conical flask. After waiting long enough for it to sweep all the air out of the flask and tube, the hydrogen is lit where it comes out of the burner.

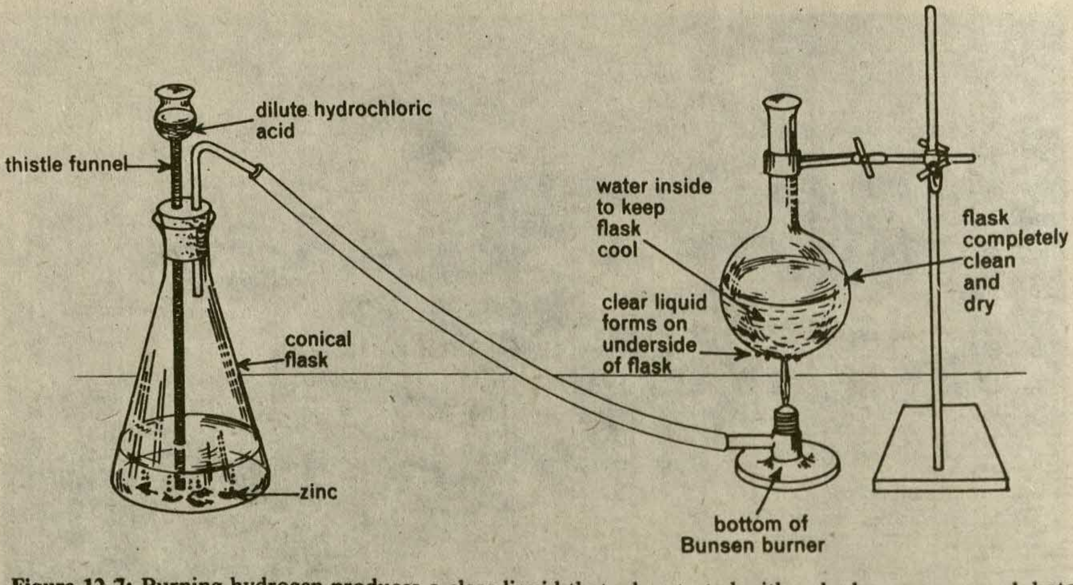

dilute hydrochloric acid
thistle funnel
conical flask
zinc
water inside to keep flask cool
clear liquid forms on underside of flask
flask completely clean and dry
bottom of Bunsen burner

Figure 12.7: Burning hydrogen produces a clear liquid that when tested with anhydrous copper sulphate proves to be water. The flask on the left, which contains hydrogen, should be wrapped in a rag when lighting the hydrogen gas. This precaution is in case the flask explodes, which could happen if there is any air mixed with the hydrogen.

The flame is allowed to play on the bottom of the flask containing cold water. After some time droplets of a clear liquid are noticed there. This liquid is obviously the product of burning hydrogen gas in air. Some anhydrous copper sulphate in a clean watch glass is pressed up against the liquid. The powder turns blue, identifying the liquid as water. Since the products of burning in air are oxides, we may conclude that water is hydrogen oxide.

Analysis of water

The apparatus shown in figure 12.8 is used to reverse the process, that is, to change water back into its elements.

The process that goes on in this apparatus is called the electrolysis of water. The electrical energy needed to decompose the water will not flow through the water if it is pure. A little sulphuric acid must be added so that electrolysis may take place.

It will be noticed that twice as much gas by volume is collected above the cathode as is collected above the anode. If each of these gases is tested in turn with a lighted match, the first gas ignites with a pop and the second gas makes the match burn more brightly. The gas from the cathode is therefore hydrogen and the other oxygen.

$$\text{Water} \longrightarrow \begin{matrix}\text{2 volumes of}\\ \text{hydrogen}\end{matrix} + \begin{matrix}\text{1 volume of}\\ \text{oxygen}\end{matrix}$$

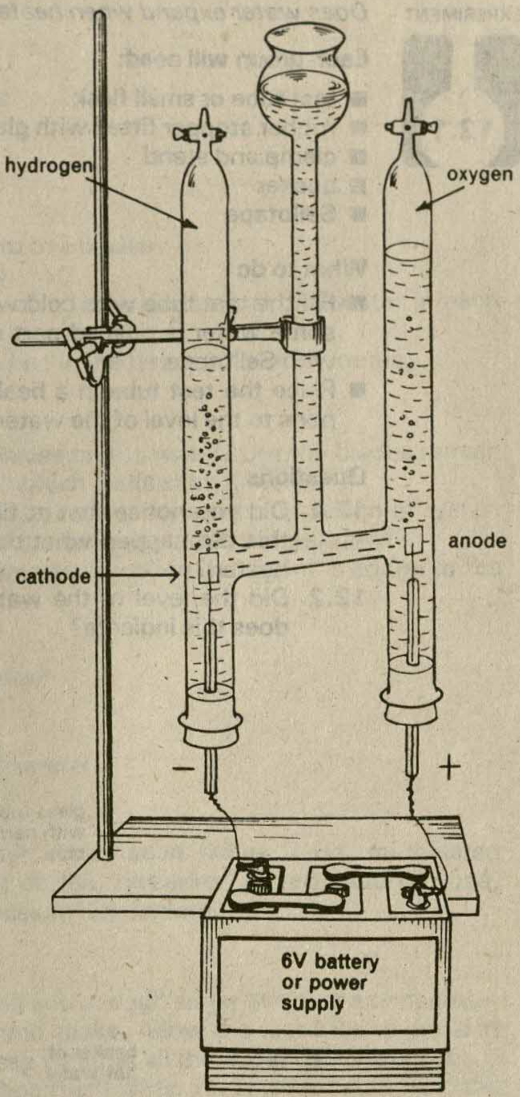


Figure 12.8: Decomposing water by electrolysis, using a voltameter fitted with platinum electrodes. The electrolyte, water, is made a little acid by adding some sulphuric acid.

EXPERIMENT 12.1

Does water expand when heated?

Each group will need:

- test tube or small flask
- rubber stopper fitted with glass tube (see figure 12.9)
- clamp and stand
- beaker
- Sellotape

What to do

- Fill the test tube with cold water, then force in the rubber stopper so that some water is pushed part of the way up the glass tube. Mark the level with Sellotape.
- Place the test tube in a beaker of hot water. Observe closely what happens to the level of the water in the tube.

Questions

12.1 Did you notice that at first the level of the water dropped slightly? If this did happen what does it indicate about the test tube when it is heated?

12.2 Did the level of the water in the narrow tube eventually rise? What does this indicate?

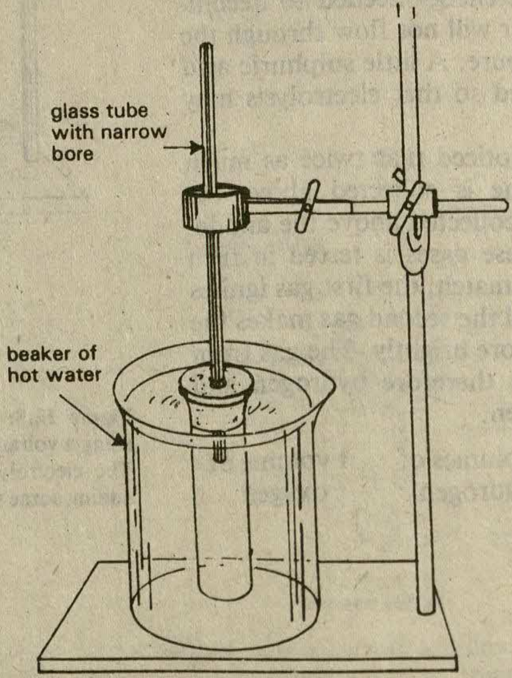


Figure 12.9: Apparatus for examining the expansion of water. A flask may be used instead of the test tube.

EXPERIMENT 12.2

Floating a steel razor blade on water

Each group will need:

- two dry steel safety razor blades
- two small beakers
- some liquid detergent

What to do

- Add a teaspoonful of detergent to one beaker.
- Fill both beakers with cold water.
- Carefully lower the flat surface of a razor blade on to the water in each beaker.
- Allow the blades to rest undisturbed in the beakers for 10 minutes.

Questions

12.3 Were you able to float the blades on the water? Did the blades remain floating on the water? If not, which blade sank first?

12.4 Detergent, like soap, is used to increase the wetting action of water. Can you explain the effect of the detergent in this experiment?

12.5 Why does washing-up become easier when detergent is added to the water?

EXPERIMENT 12.3

What substances are soluble in water?

Each group will need:

- a number of test tubes 2 cm in diameter
- test tube rack
- stoppers to fit the test tubes
- small quantities of sugar, butter, flour, soap flakes (Lux), methylated spirits, olive oil, cocoa, instant coffee, glycerine, bicarbonate of soda, liquid detergent, powdered potassium dichromate

What to do

- Half fill a test tube with water and add enough sugar to cover a cent piece. Place a stopper in the test tube and shake. Allow the test tube to stand in the rack for about 2 minutes to see whether all the sugar has dissolved.
- Repeat, using a clean test tube and fresh water for each substance. If the substance to be tested is a liquid, add about half a teaspoonful to the test tube.
- Copy and complete the following table.

Substance added to water	Is the substance soluble, slightly soluble or insoluble?

Question

12.6 If you were in doubt about the solubility of a substance, what test would you use to see whether any of it had dissolved?

EXPERIMENT

12.4

Showing that water may help substances to react

Each group will need:

- two small test tubes with stoppers
- powdered lead nitrate
- powdered potassium dichromate

What to do

- Take a little of each of these dry powders and mix the two on a sheet of paper. Did anything happen?
- Next, prepare solutions of lead nitrate and potassium dichromate. About one-quarter fill each test tube with water. Add enough lead nitrate to cover a cent piece to one and the same amount of potassium dichromate to the other. Shake to dissolve.
- Pour the contents of one test tube into the other.

Questions

12.7 What happened when the two solutions were mixed? Would you agree with the statement that a dry mixture of lead nitrate and potassium dichromate will not react but solutions of the two substances in water will react?

12.8 Have you ever heard anyone say "It isn't good to drink while eating"? Actually the reverse is true. Water plays an important part in digestion. It is therefore beneficial to drink water during a meal. Can you guess why?

EXPERIMENT

12.5

What makes water "hard"?

Each group will need:

- four 2 cm width test tubes with stoppers
- Epsom salt
- soap flakes (Lux)
- washing machine powder
- distilled water
- liquid detergent

What to do

- Half fill the four test tubes with distilled water. Fit the stoppers.
- Add a "cent-full" of Epsom salt to two of the test tubes and shake to dissolve the salt.
- Spread out about 6 Lux flakes, all approximately equal in size.

- Add one Lux flake to the distilled water in one of the remaining test tubes and shake to produce a lather. Allow to stand for about 20 seconds. If the lather disappears add another flake and shake. Repeat if necessary until the lather lasts 20 seconds.
- Next add Lux flakes one at a time, with shaking, to one of the test tubes containing the Epsom salt solution. Note how many Lux flakes you need to add to produce the same lather as you had with the distilled water.
- Repeat the experiment using the washing powder instead of the Lux flakes. Use a cent piece to measure out the powder.
- Repeat using drops of detergent.
- Copy the following table and record your results:

	No. of Lux flakes	"Cent-fulls" of washing powder	Drops of detergent
Distilled water			
Hard water			

Questions

12.9 Hard water is water that will not lather readily with soap. Did the Epsom salt make the distilled water hard? Did you notice anything happening to the hard water as the flakes were added?

12.10 Was it easier to produce a lather with the washing powder?

12.11 Do washing machine powders contain more than simple detergents to produce a lather?

12.12 Repeat the experiment testing tap-water and sea water for hardness.

Water

Water:

1. dissolves many substances
2. circulates continually in nature
3. expands on freezing
4. has a high surface tension
5. is made "hard" by certain substances
6. turns anhydrous copper sulphate blue
7. is formed when hydrogen burns in air
8. is a compound, hydrogen oxide
9. may be decomposed into 2 volumes of hydrogen and 1 volume of oxygen.

Spelling list

aerate
analysis
anhydrous
anode
cathode
concrete
condensation
cycle
detergent
distil
distilled
electrode
electrolysis
freeze
precipitation
synthesis

Things to do

12.13 What weight of dissolved solids is present in one litre of sea water? Use a 25 mL pipette to measure out 25 mL of sea water and evaporate it to dryness on a weighed clock glass. Multiply the weight of salt by 40 to obtain the answer.

12.14 How much does water expand when it freezes? Three-quarters fill a flat-bottomed specimen tube with water and mark the level with Sellotape. Stand the tube in a narrow-necked bottle to keep it upright and place it in the freezing compartment of a refrigerator.

12.15 Making water with a bang.

Decompose some water by electrolysis, as shown in figure 12.10. The bubbles coming out of the detergent will contain hydrogen and

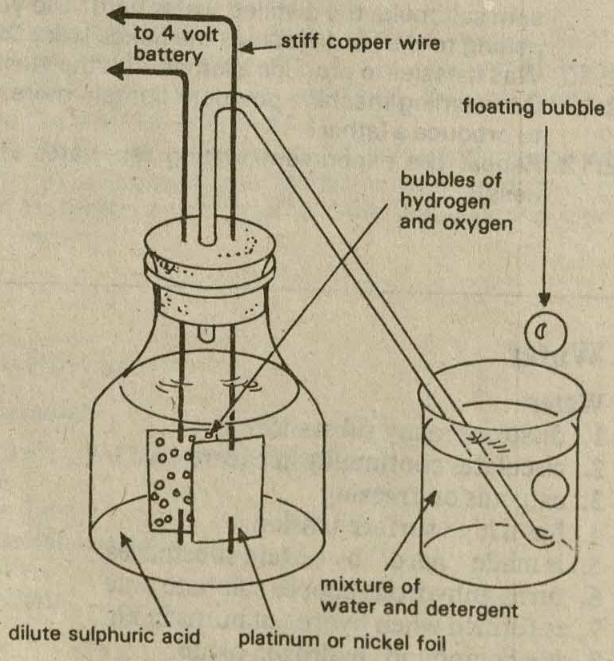


Figure 12.10: Apparatus for making bubbles of a mixture of hydrogen and oxygen in the proportion to form water. *Warning:* Hold the flame to freely floating bubbles only. The bottle may explode if a flame is held at the end of the glass tube.

oxygen in the correct ratio to recombine back into water again. As a bubble floats away from the detergent, light it with a taper.

Warning: Do not hold a lighted taper near the end of the outlet tube. Why?

12.16 Wet a handkerchief and hold it firmly and tightly across the top of a tumbler completely filled with water. Turn the tumbler upside down. Does the water behave as though it has a skin across it that prevents it flowing through the small holes in the handkerchief?

12.17 Completely fill a tumbler with water. How much more water can you add by using a pipette as a dropper?

More questions

12.18 Where does your domestic water supply come from? How is it stored and how is it treated before it is delivered to the customers?

12.19 How would you test a colourless liquid to find out if it was pure water, not water mixed with other substances?

12.20 If 10 grams of fresh lettuce were dehydrated (that is, all water removed), approximately what weight of material would remain?

12.21 Is water a compound, mixture or element? Give reasons for your answer.

12.22 Which of the following types of water do you think would contain the fewest impurities and which the most: rainwater, tap-water, sea water, bore water, river water? How would you verify your choice?

12.23 Why is the dissolved air in water important to animals and plants that live in rivers and seas?

12.24 What is anti-freeze and why is it added to the water in a car radiator? Why wouldn't common salt do as an anti-freeze?

Test yourself (chapter 12)

Write the answers to the following in your workbook:

1. What name is given to the circulation of water in nature, from sea to land and back to sea again?
2. Where does the energy come from that causes this circulation?
3. What is the colour of anhydrous copper sulphate?
4. When water freezes it ____________.
5. Water that will not lather readily with soap is said to be ____________.
6. Water that contains dissolved air is said to be ____________.

In each of the following questions, choose the best answer and write its letter in your workbook:

7. On analysis, water will decompose into:
   (a) two volumes of oxygen and one volume of hydrogen
   (b) one volume of oxygen and one volume of hydrogen
   (c) one volume of oxygen and two volumes of hydrogen
   (d) two volumes of oxygen and two volumes of hydrogen.

8. A water strider can walk on water because:
   - (a) it has practically no weight
   - (b) the water behaves as though it has a skin over it
   - (c) water striders have long thin legs
   - (d) water striders have air bubbles under their bodies.
9. Soft drinks are aerated to make them:
   - (a) lighter
   - (b) last longer
   - (c) taste better
   - (d) look better.
10. A test for pure water is:
    - (a) it freezes at 0°C
    - (b) it boils at 100°C when the atmospheric pressure is 76 cm of mercury
    - (c) it turns anhydrous copper sulphate blue
    - (d) all of the above tests
    - (e) tests (a) and (b) only
    - (f) tests (a) and (c) only
    - (g) tests (b) and (c) only.

13

Solutions and crystals

In chapter 12 various substances were tested for solubility in water. Some of these disappeared when shaken with the water. These substances are said to be soluble. They are distributed evenly throughout the liquid to form a type of mixture called a solution.

The process of solution is widespread in nature. Water flowing from the mountains to the sea dissolves a variety of solids from the soil and rocks over which it flows. These dissolved solids cause the salinity of the oceans. The process of solution is also of great importance to living things. The food absorbed by the cells of organisms is dissolved in a watery medium. So too is the waste material that these cells excrete after using their food.

Water, however, is not the only solvent. Many others are used in industrial processes. Ether, for example, is used to extract fats and oils from some types of dead plants and animals. In this chapter the process of solution will be studied.

The nature of a solution

In experiment 1.2 (page 5) the salt solution passed through the filter paper. In fact, all solutions can pass through the fine pores of a filter paper. The dissolved substance, called the solute, must therefore be in an extremely finely divided condition.

Indeed, the solute particles are so tiny they are invisible and the solution containing them is transparent. In addition, the solute and the solvent are so thoroughly mixed in a solution that one part of the solution is the same as any other. Efforts to separate solute and solvent by gravity or centrifuging are quite unsuccessful. Recovery of the solute is possibly only by evaporating the solvent, as was done in experiment 1.2.

Factors affecting the rate of solution

The following experiment demonstrates those factors affecting the rate at which a solid dissolves in water. Four test tubes each 2 centimetres wide are taken and 20 millilitres of water are added to each. About one gram of coarse sodium nitrate crystals is set aside to be added to one tube and three lots of fine sodium nitrate crystals, each weighing one gram, are set aside for the other three tubes. Figure 13.1 shows what is done with each tube. The time the crystals take to dissolve is noted in each case.

The results obtained show us that the rate at which a solid will dissolve in water may be increased by:

- using a solid in a more finely divided condition

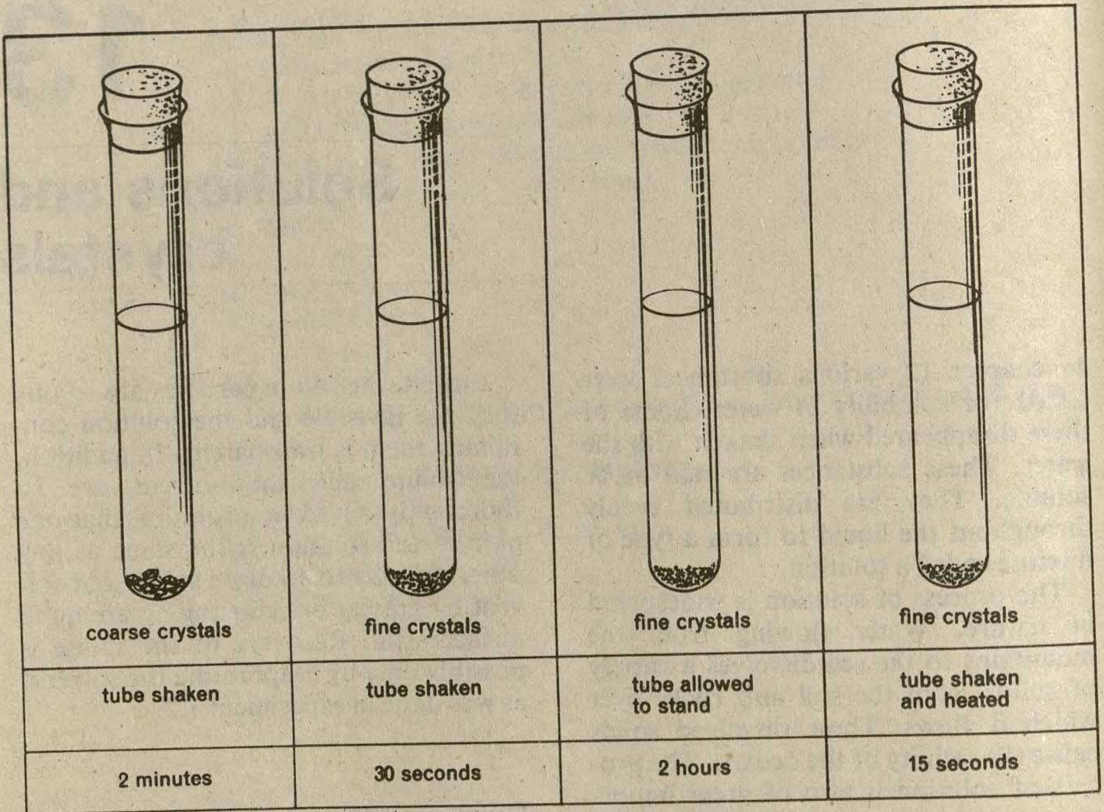


Figure 13.1: Rates of solution. The times given are those taken for the crystals to dissolve completely.

- shaking the solution while the solid is dissolving
- warming the solution while the solid is dissolving.

A saturated solution

The rate at which a solid will dissolve decreases as more of the solid goes into solution. This can be readily shown by adding one-gram portions of fine sodium nitrate crystals to one of the test tubes used in the previous experiment. It is found that each additional amount takes more time to dissolve than the previous amount.

Eventually no more crystals go into solution. At this stage the solution is said to be *saturated*. A saturated solution at any particular temperature is one that contains as much of the solute as possible. We can be sure that a solution is saturated only if the solution contains undissolved particles of the solute.

The different solubilities of substances

Sugar is very soluble in water. At 20°C it is possible to dissolve about 200 grams in 100 millilitres of water. On the other hand, only 0.2 gram of slaked lime will dissolve in the same amount of water. Slaked lime is said to be slightly soluble. Substances such as chalk are regarded as being insoluble in water, but even chalk dissolves to a very slight extent, the solubility being 0.002 gram per 100 millilitres of water. Most people would consider gold to be an insoluble substance. However, scientists have estimated that a cubic kilometre of the ocean contains 4 kilograms of dissolved gold.

Solvents other than water

So far we have been discussing one solvent only, that is, water. The following experiment shows that other liquids can also act as solvents for solids.

A few crystals of iodine are added to some water in a test tube. (Tweezers are used to pick up the crystals, because contact with iodine can stain the skin brown.) It is noticed that the crystals do not dissolve in the water. A few more iodine crystals are now added to some methylated spirits in a test tube. This time the crystals dissolve to form a brown solution. Methylated spirits is therefore a solvent for iodine.

Experiment 13.1 tests other liquids and solids to see whether they form solutions.

Experiments with a bottle of soft drink

Soda water is the name given to a solution of carbon dioxide in water. Soda water is bottled under pressure. Soft drinks are simply soda water to which flavouring has been added.

A bottle of soft drink is examined carefully. No bubbles are evident in the liquid. The top is removed and immediately bubbles begin to rise to the surface from the liquid. These are bubbles of the dissolved gas, carbon dioxide. They have come out of solution because carbon dioxide is less soluble when the pressure is reduced.

Some of the soft drink is poured into a beaker and the contents warmed. More bubbles of gas now leave the liquid, showing that the gas is less soluble in hot than in cold water. It is generally true that gases are less soluble in hot liquids than in cold liquids.

Solutions of liquids in liquids

When solids or gases dissolve in a liquid there is a limit to the amount of substance that can dissolve at the temperature of the experiment. Once the solution is saturated no more will dissolve.

Is there a limit to the amount of a liquid that will dissolve in another liquid? The following demonstration answers this question:

About ten millilitres of water is placed in each of three test tubes. One-millilitre portions of alcohol, glycerine and kerosene are added to the separate tubes. Each tube is shaken. The alcohol and glycerine dissolve in water but the kerosene does not.

Now one-millilitre portions of water are added to separate test tubes containing ten millilitres of alcohol, glycerine and kerosene. Each tube is shaken. The water dissolves in the alcohol and glycerine but not in the kerosene. It can be shown that water and alcohol mix in all proportions, as do water and glycerine. These liquids are said to be *miscible*, that is, one is soluble in the other.

The kerosene and water did not dissolve in each other. They are said to be immiscible.

Change of solubility with temperature

We have already observed that warming a solution while a solid is dissolving increases the rate at which it dissolves. Does this mean that solids are more soluble in hot water than in cold? Experiments show that this is so — that is, the solubility of most solids in water does increase with rise in temperature. Common salt, however, shows only a small increase in solubility and calcium hydroxide actually shows a decrease in solubility with increase in temperature. Figures 13.2 and 13.3 are graphs of the solubilities of these solids in water at different temperatures.

Obtaining a saturated solution by cooling

Getting the last portion of a solute to dissolve to obtain a saturated solution at a given temperature takes a long time. With those substances whose solubilities increase with temperature, a saturated solution can be obtained more quickly by cooling the solution from a higher temperature. As the solution cools, part of the substance crystallizes out and a saturated solution is left. This method is used in experiment 13.2 to prepare a saturated solution of copper sulphate.

Crystals

Crystals are solids having a regular geometrical shape. (See figure 13.4, facing page 185.) Different solids often have different crystalline shapes. This can be explained by saying that the particles are arranged differently in the different solids. Crystals may form when a molten substance solidifies, or when a dissolved substance comes out of solution on cooling or on evaporation.

Growing a large crystal of alum

The first step in growing a large crystal

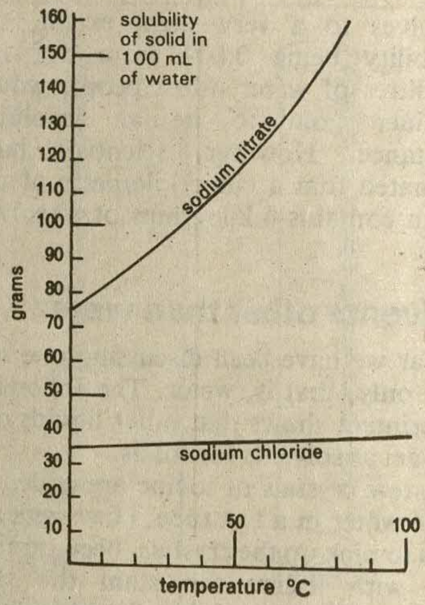


Figure 13.2: The top graph shows that a lot more sodium nitrate dissolves in hot water than in cold water. The bottom graph shows that very little more sodium chloride can be dissolved in hot water than in cold water.

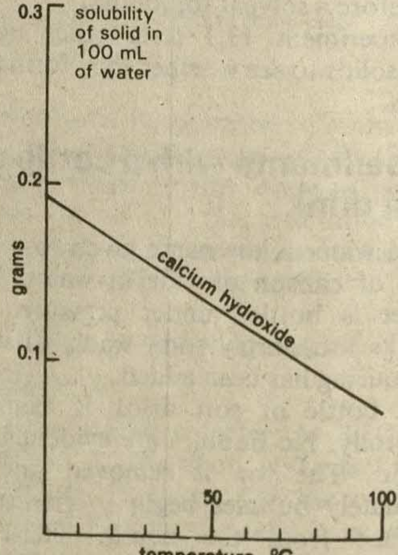


Figure 13.3: Calcium hydroxide is an unusual substance. It is less soluble in hot water than in cold water.

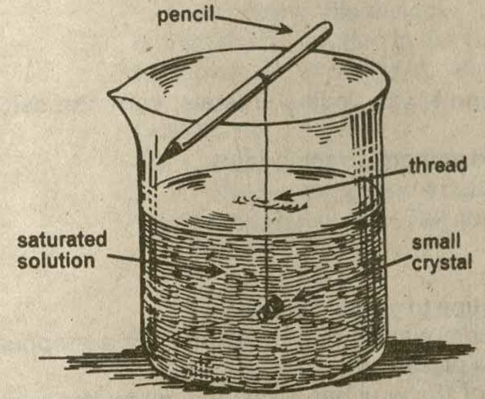


Figure 13.5: Growing a large crystal by "seeding" a saturated solution.

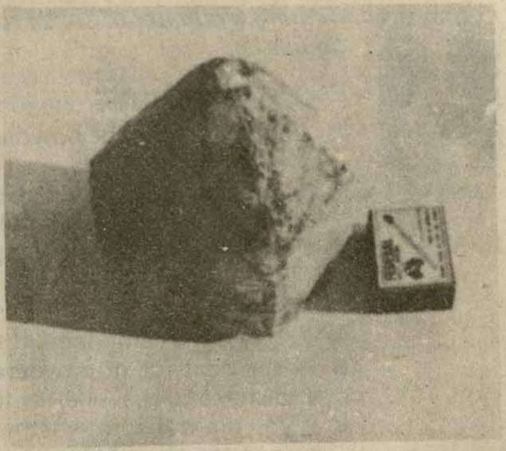


Figure 13.6: A large quartz crystal. Note the roughly hexagonal shape.

of alum is to make a hot saturated solution of potash alum. Before the solution has cooled it is decanted into a clean beaker, leaving behind any undissolved solid. A small, well-formed alum crystal is selected and suspended in the solution by means of a fine thread, as shown in figure 13.5. As the solution cools this crystal will grow. The saturated solution in which the crystal grows is called the *mother liquor*. When the crystal has formed it is advisable to remove it, for if the temperature of the solution should rise, the crystal will dissolve.

Figure 13.6 is a photograph of a large quartz crystal formed in nature by the slow cooling of a hot aqueous solution of silica.

Water of crystallization

In chapter 9 we saw that blue copper sulphate gives off water when heated. This water is called *water of crystallization*. When the crystals lose it, their crystalline shape is destroyed. Many solids form crystals that contain water of crystallization, but there are also many crystals that do not contain water. Alum crystals, for example, contain water of crystallization, but sodium chloride crystals do not.

Effect of exposing some substances to the atmosphere

Some caustic soda and some calcium chloride, both white solids, are placed in separate watch glasses and left exposed to the air. After some time both watch glasses contain solutions of the solids placed in them. The substances have absorbed enough water from the air to enable them to dissolve. Such substances as caustic soda and calcium chloride are said to be *deliquescent*.

Crystals of some substances do just the opposite, that is, they lose water to the air. Obviously, only those crystals that contain water of crystallization could possibly do this. Some washing soda crystals are left exposed to the air. If the conditions are dry enough the clear crystals will turn opaque and white. This change is due to loss of water of crystallization. Such substances are said to be *efflorescent*.

EXPERIMENT 13.1

Testing a number of solids to see whether they are soluble in some selected liquids

Each group will need:

- small quantities of powdered candle wax, iodine crystals, common salt, sulphur and Vaseline
- turpentine, methylated spirits and carbon tetrachloride
- several small test tubes with stoppers
- three watch glasses

What to do

- Add about a centimetre of turpentine to a small test tube.
- Add a cent-full of powdered candle wax to the turpentine. Fit a stopper and shake to see whether the wax dissolves.
- If you are not sure whether any of the wax has dissolved, allow the mixture to stand so that any undissolved material may settle. Carefully decant some of the clear liquid from the top of the mixture into a watch glass. Allow the watch glass to stand in a warm draughty place to assist the turpentine to evaporate. Any residue of wax on the watch glass indicates that it is soluble in turpentine.
- Now test the other solids with each of the liquids in turn. Copy and fill in the following table. State whether each substance is soluble, slightly soluble or insoluble.

Solute	Solvent		
	Turpentine	Methylated spirits	Carbon tetrachloride
Candle wax			
Iodine			
Common salt			
Sulphur			
Vaseline			

EXPERIMENT 13.2

Making saturated solutions of copper sulphate, Epsom salt and hypo

Each group will need:

- 100 mL beaker
- tripod
- gauze
- Bunsen burner
- quantities of powdered copper sulphate, Epsom salt and hypo
- glass stirring rod

What to do

- Pour about 50 mL of water into the beaker. Heat the water with a Bunsen burner until it is hot but not boiling.
- Add copper sulphate, a little at a time, and stir to assist it to dissolve. Repeat this until no more copper sulphate will dissolve.
- Allow the beaker to stand so that the undissolved copper sulphate settles to the bottom.

- Decant some of the clear saturated solution out of the beaker into a clock glass. Allow this to cool.
- Watch the solution in the clock glass closely.
- Repeat the experiment, using first Epsom salt and then hypo.

Questions

13.1 Did any crystals of copper sulphate form on the clock glass? Can you say anything about the shape of the crystals?

13.2 Compare the crystal shapes of copper sulphate, Epsom salt and hypo.

Solutions and crystals

1. A solution:
    - is a uniform mixture of one substance in another
    - consists of two parts — solute and solvent
    - is saturated when it contains all the solute it can normally dissolve at that temperature.
2. Solubility:
    - of solids usually increases with rise in temperature
    - of gases usually decreases with rise in temperature
    - of gases usually increases with increase in pressure.
3. Crystals:
    - of a solid have regular geometrical shape
    - form when a solid comes out of solution on cooling
    - form when a molten substance solidifies
    - may contain water of crystallization.

Spelling list

alcohol
crystal
crystallize
deliquescent
efflorescent
gas
gases
opaque
saturated
solubility
solute
solution
solvent
stir
stirring

Things to do

13.3 Prepare a gas jar of ammonia by heating a mixture of ammonium chloride and slaked lime in a test tube, as shown in figure 13.7 (next page). Place a cover slip over the gas jar and place it mouth downwards in a large beaker of water. Remove the cover slip. What happens?

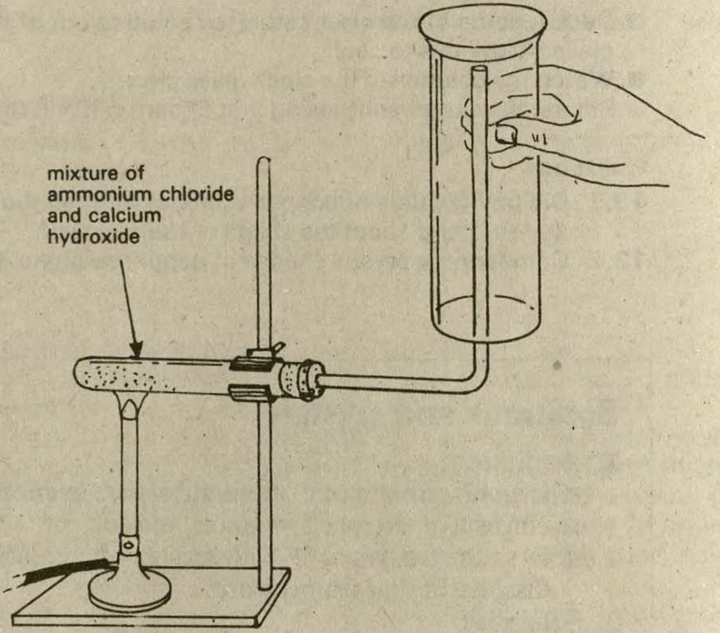


Figure 13.7: Apparatus used for preparing and collecting a gas jar of ammonia.

13.4 Fill a small narrow-necked flask with water until the level is part of the way up the neck. Mark the level. Add common salt, a little at a time, with continual shaking. Use a stopper to avoid spillage. You will notice that there is practically no rise in water level. Why? Where has the salt gone?

13.5 Repeat the experiment in 13.4, this time dissolving 50 mL of alcohol in 50 mL of water in a measuring cylinder. What happens?

More questions

13.6 Why is the ocean salty? Where has all the salt come from? Why has the Dead Sea such a high salt content and the Baltic Sea such a low salt content?

13.7 Sometimes you see a dam on a farm in which the water is discoloured by clay in suspension. What is the difference between a solution and a suspension? Why is it that the clay suspension never settles?

13.8 What is the cause of divers' "bends"?

13.9 Which of the following would you classify as solutions?

milk
orange juice
lemonade
petrol
blood
sea water
pure water
house paint

Test yourself (chapter 13)

Write the answers to the following in your workbook:

1. Complete each of the following sentences by using one word for each.
   (a) The substance that dissolves is called the ________.
   (b) The liquid in which it dissolves is called the ________.
   (c) The resultant mixture is called a ________.
2. Name a solvent that can be used to dissolve:
   (a) methylated spirits
   (b) sugar
   (c) petrol
   (d) iodine
   (e) carbon dioxide.
3. Complete the following sentences:
   (a) Small crystals are formed when a saturated solution cools ________.
   (b) Large crystals are formed when a saturated solution cools ________.

In each of the questions 4 to 7, choose the best answer and write its letter in your workbook.

4. When sugar dissolves in tea, it disappears because it is:
   (a) melted by the tea
   (b) hidden by the colour of the tea
   (c) decomposed by the tea
   (d) separated into very small particles in the tea.
5. A space traveller returns with a sample of liquid from a distant planet. He boils some of the liquid in a beaker. Eventually all traces of liquid disappear and small crystals remain in the beaker. He concludes that the original liquid was:
   (a) a compound
   (b) a pure substance
   (c) a mixture
   (d) pure water.
6. In order to dissolve a solid quickly in a solvent it is best to:
   (a) use large particles of the solid
   (b) heat a mixture of solid and solvent
   (c) shake a mixture of solid and solvent
   (d) grind the solid to a powder before adding it to the solvent
   (e) use more than two of the above.
7. Some lemonade was warmed in a dish and allowed to cool. It tasted flat because:
   (a) the lemon flavouring is destroyed by heating
   (b) carbon dioxide is less soluble in warm water than in cold
   (c) dissolved air is driven out by heating
   (d) the lemon flavouring is driven out of the lemonade by heating.

14

Rocks and minerals

As we move around in our own district or travel further afield through the countryside, we see rocks everywhere. These rocks may be pieces lying on the ground, the walls of a road cutting, a cliff face or a mountain range. Rocks can tell us a great deal about the landscape. For example, they may tell us whether there has ever been a volcano in the area, or whether the area has been under water in the distant past.

Look at the photographs 14.1 and 14.2 — one from Queensland and the other from New South Wales. These formations have similar shapes. Were they formed in the same way? By examining rock samples from each, we know that the Glasshouse Mountains are the cores of extinct volcanoes whereas Mount Banks is the remains of a body of sedimentary sandstone laid down beneath the sea.

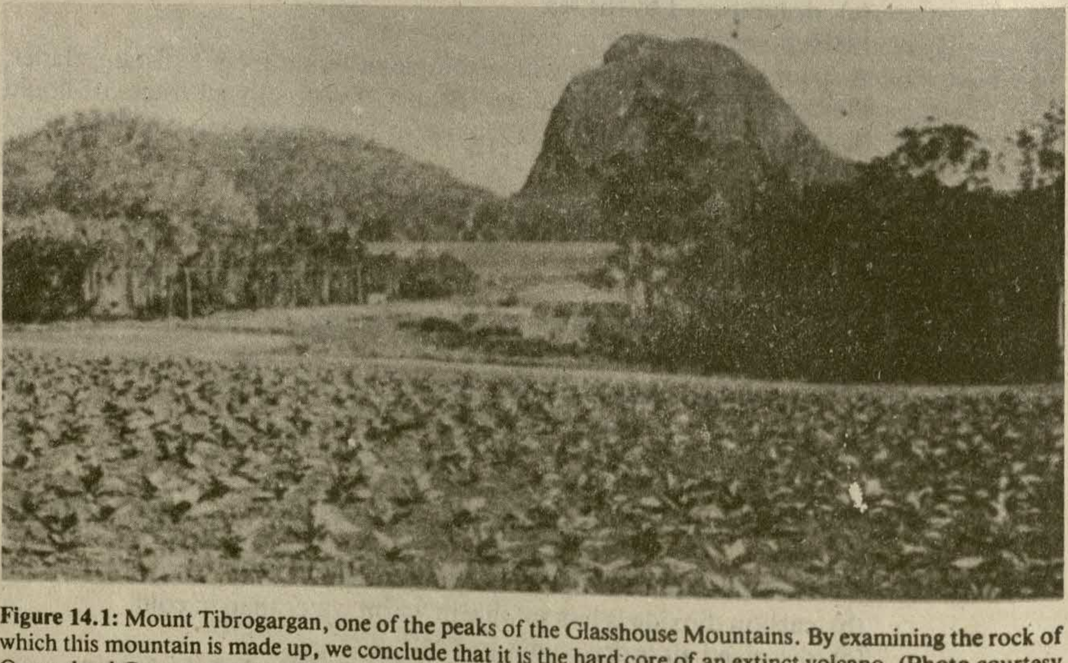


Figure 14.1: Mount Tibrogargan, one of the peaks of the Glasshouse Mountains. By examining the rock of which this mountain is made up, we conclude that it is the hard core of an extinct volcano. (Photo courtesy Queensland Government Tourist Bureau)

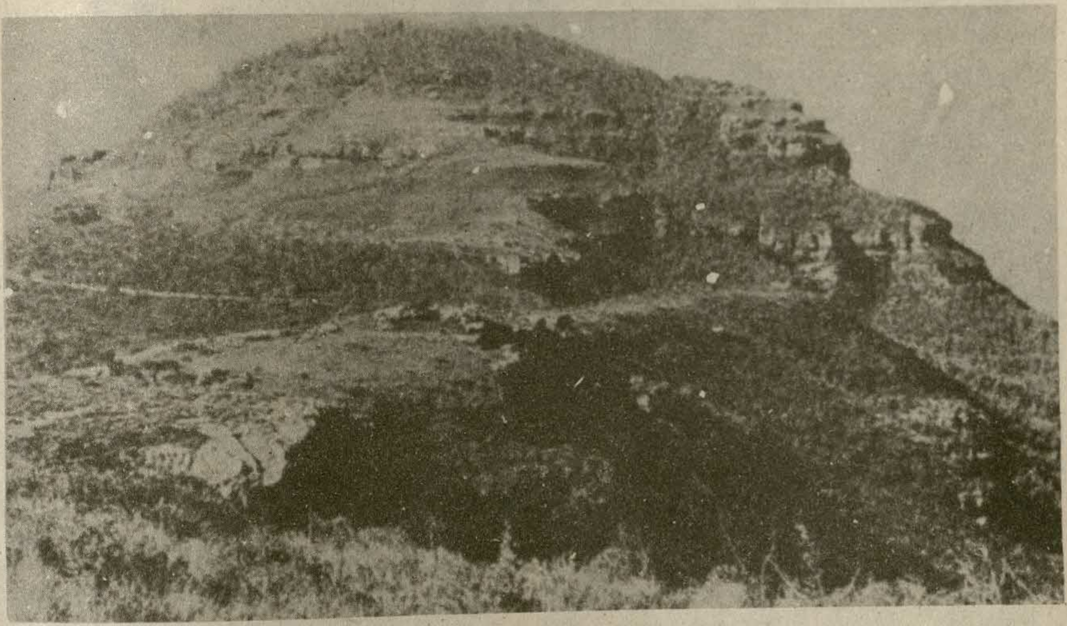


Figure 14.2: Mount Banks, in the Blue Mountains of New South Wales. This peak is made up of sandstone formed beneath the sea millions of years ago. It is higher than the surrounding tableland because it has a basalt capping. Basalt is more resistant to erosion than is sandstone.

The grains in a rock

In order to identify rocks we must first know something about the grains they contain. As an illustration, let us examine two totally different rocks — *granite* and *conglomerate*, as shown in figures 14.3 and 14.4, on page 152.

You will notice that granite is composed of crystalline grains — the grains mostly have flat faces and sharp edges. Granite is formed from molten material, which crystallizes deep beneath the earth's surface. It is called an igneous rock.

Conglomerate, on the other hand, is composed of rounded or partly rounded grains. These grains have been rounded by the grinding action of water, tumbling them along the bed of a stream. Eventually they have settled as sediments on the floor of a lake or ocean and over the years have hardened to form a rock. Conglomerate is called a sedimentary rock.

Minerals

As you look at a piece of granite you will notice that some of the grains are black, some are clear like glass and others are white or pink. These different-coloured materials are minerals. All rocks are made up of minerals and although there are many different kinds of minerals, only a few are common. Some common minerals are:

- quartz
- feldspar
- mica
- hornblende
- calcite
- iron oxide.

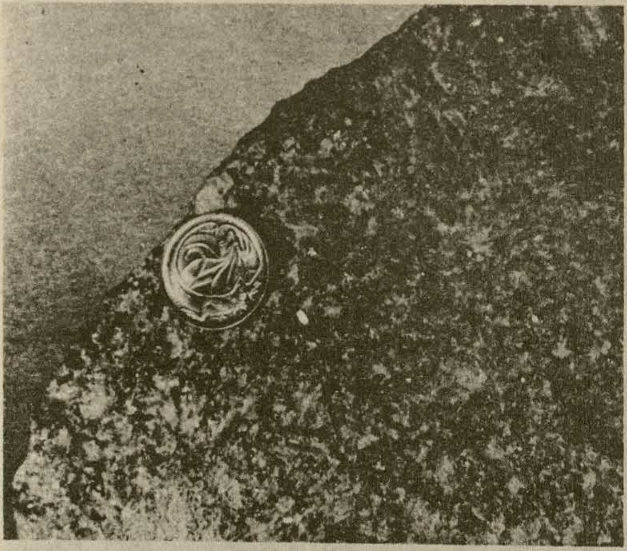


Figure 14.3: A piece of granite. Note the crystalline nature of the grains. They have sharp edges and flat surfaces.

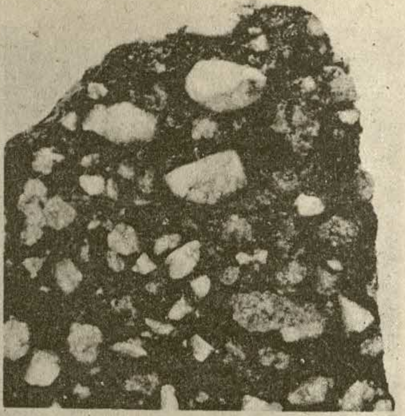


Figure 14.4: A piece of conglomerate. Note the partly rounded nature of the large grains. The rounding was caused by the grains' tumbling along the bed of a mountain stream. They finally came to rest on the bed of a lake, where they were cemented together to form a rock.

Identification of minerals

What are some of the things about minerals that help us to identify them in rocks?

Shape. Some minerals can be identified by their crystalline form. For example, mica always occurs as flaky crystals.

Hardness. Quartz is a hard mineral, whereas mica is soft.

Colour. Feldspar is light-coloured; hornblende is almost black.

Cleavage. This is the way a piece of a mineral tends to break when struck with a hard object. For example, calcite splits easily and always keeps the same shape. We say it has excellent cleavage. Quartz, on the other hand, breaks irregularly. We say it has no cleavage.

Appearance. Quartz is transparent like glass, but feldspar is opaque.

Some common minerals

Quartz is a transparent mineral that is very hard: it scratches steel. It forms six-sided crystals but has no cleavage planes like calcite. (Cleavage planes are the flat surfaces formed when the mineral breaks.) If struck, quartz fractures with a curved surface (this is called conchoidal fracture).

Feldspar is harder than calcite but softer than quartz. It has two cleavage planes almost at right angles. Grains of feldspar often show parallel lines on their surfaces. Feldspar is light-coloured, occurring in rocks as white, pink or yellow crystals.

Micas are very soft minerals. They may be scratched by a fingernail. They flake easily; thin sheets may be peeled off a mica. There are two common kinds of mica — biotite, which is black, and muscovite, which is white.

Hornblende is dark in colour and almost as hard as feldspar. It has two cleavage planes at about 60° to each other. It is usually duller in appearance than black mica.

Calcite is a white mineral, harder than mica but softer than feldspar. It has three cleavage planes at 75° to each other. It reacts with dilute hydrochloric acid to produce bubbles of gas (carbon dioxide).

Iron oxide. Haematite, limonite and magnetite are all oxides of iron. Haematite is reddish-grey, limonite is yellow and magnetite is black.

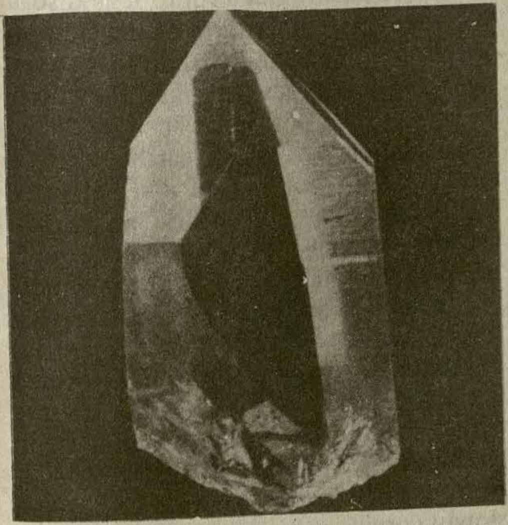


Figure 14.5: A crystal of quartz. Quartz crystals have six sides and do not break cleanly.

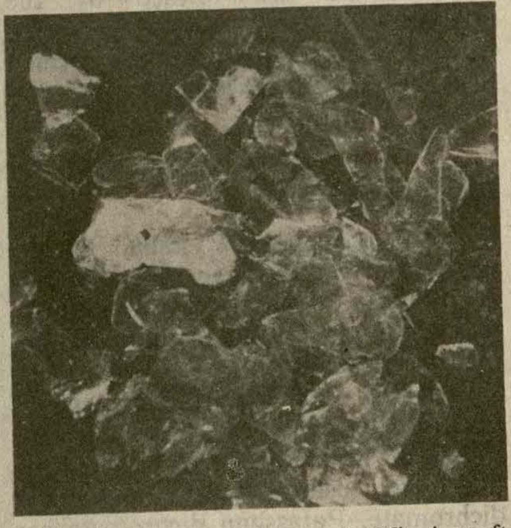


Figure 14.6: Flakes of mica crystals. Mica is a soft mineral that flakes very easily.

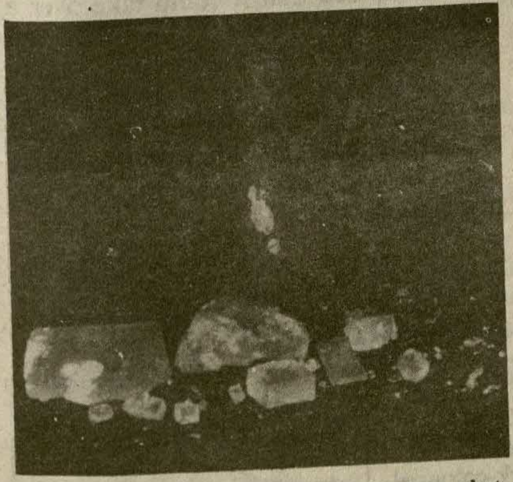


Figure 14.7: A piece of calcite that has been shattered by a blow from a hammer. Calcite breaks into flat-sided pieces with faces that are at about 75° to each other.

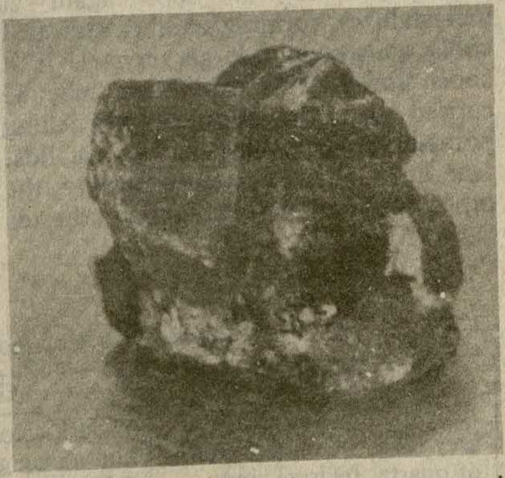


Figure 14.8: A piece of rock containing a crystal of feldspar. Notice the flat faces of the crystal, which are almost at right angles to one another.

Rocks

Rocks may be classed as *igneous* or *sedimentary*. (There is another group of rocks called *metamorphic* rocks, but we are not going to discuss them here.) As a rough approximation we can say that igneous rocks are formed by the crystallization of molten material, whereas sedimentary rocks are formed from sediments in lakes and oceans.

Igneous rocks

Igneous rocks have crystalline grains, which are interlocking. Igneous rocks are usually easily distinguished from sedimentary rocks, one reason being that the latter often have rounded grains.

The size of the crystals in igneous rocks is determined by the length of time it took the crystals to form. This may be illustrated using molten potassium dichromate. Potassium dichromate has no water of crystallization and when it is heated it melts without decomposition. When allowed to cool again it recrystallizes, forming small crystals if it cools quickly and larger crystals if it cools slowly. This experiment may be carried out in the laboratory by melting potassium dichromate in two tin lids. One lid is allowed to cool quickly; the other lid is cooled slowly on an asbestos mat over a low Bunsen flame. Examination with a hand lens will show that the slow-cooling material contains the larger crystals.

Rock material deep beneath the earth's surface is molten. We see this molten material flowing out of active volcanoes when they erupt. It is also a fact that the temperature at the bottom of a deep mine is higher than that at the surface. The deeper the mine, the hotter it is at the bottom. Therefore the material well below the earth's surface must be very hot indeed and, at great depths, hot enough to melt. This molten material is called *magma*. Being fluid, the magma can flow into any weakness in the crust above and may work its way to the surface. If this magma solidifies beneath the surface, the rocks formed are called intrusive rocks. If the magma flows over the surface and then solidifies, the rocks are extrusive.

Plutonic rocks. Rocks produced from slowly cooling magma deep in the crust are called plutonic rocks after Pluto, the Roman god of the underworld. It has been estimated that it could take over a million years for magma to solidify and form plutonic rocks. This slow cooling produces mineral grains large enough to be seen with the naked eye. Examples of such crystalline rocks are granite, usually light pink or grey, and gabbro, a dark, heavy rock.

Table 14.1: Common plutonic igneous rocks

Granite	Gabbro	Dolerite
A light-coloured pink or grey rock. It contains grains of quartz, feldspar and dark minerals such as mica and hornblende.	A dark-coloured rock containing grains of feldspar and dark-coloured minerals. It has no quartz.	Similar to gabbro but finer grained because it crystallizes nearer the surface.

Table 14.2: Common volcanic igneous rocks

Rhyolite	Pumice	Basalt
A light-coloured, very fine-grained rock containing the same minerals as granite. The mineral grains cannot be seen with the naked eye. The rock sometimes shows flow bands.	A light-coloured, very fine-grained rock. It is porous, containing many air holes. These holes were formed by gas escaping from lava. The rock floats on water.	A dark-coloured, very fine-grained rock containing the same minerals as gabbro. As with other volcanic rocks, the mineral grains cannot be seen with the naked eye.

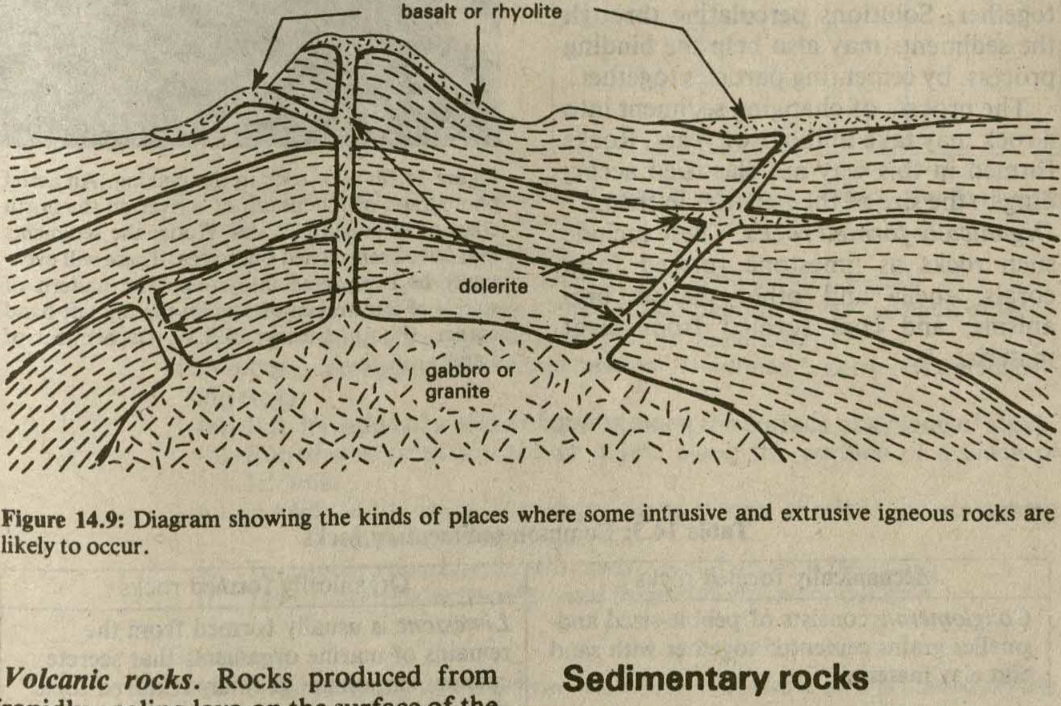


Figure 14.9: Diagram showing the kinds of places where some intrusive and extrusive igneous rocks are likely to occur.

Volcanic rocks. Rocks produced from rapidly cooling lava on the surface of the earth are called volcanic rocks. The time taken for these to solidify varies with the thickness of the lava but would be only days or weeks. The mineral grains in volcanic rocks are too small to be seen by the naked eye. Examples of volcanic rocks are rhyolite, a light-coloured rock, and basalt (called "blue metal" when broken up), a dark-coloured rock.

Sedimentary rocks

Sedimentary rocks are formed by the pressing together or cementing of material broken down from other rocks or from the remains of dead organisms.

Mechanically formed rocks. Moving water, wind and moving ice can all carry rock sediments. Rocks formed from these sediments are said to be mechanically formed.

Far more sedimentary rocks have been formed by moving water than by wind and ice. The sediments carried by water are usually well rounded because sharp corners tend to be worn away as the particles are rolled along. When the moving water slows down and can no longer carry its load, the sediments are deposited. After deposition the sediments are compacted into rock by the pressure of the overlying material. This pressure squeezes out much of the water and assists the fine particles, such as clays, to bind the larger particles together. Solutions percolating through the sediments may also help the binding process, by cementing particles together.

The process of changing sediment into a rock may take millions of years. Rocks formed in this way are classified according to the size of the particles in them.

Organically formed rocks. These include such rocks as limestone formed from corals, shells and other marine organisms, and coal formed from plant material.

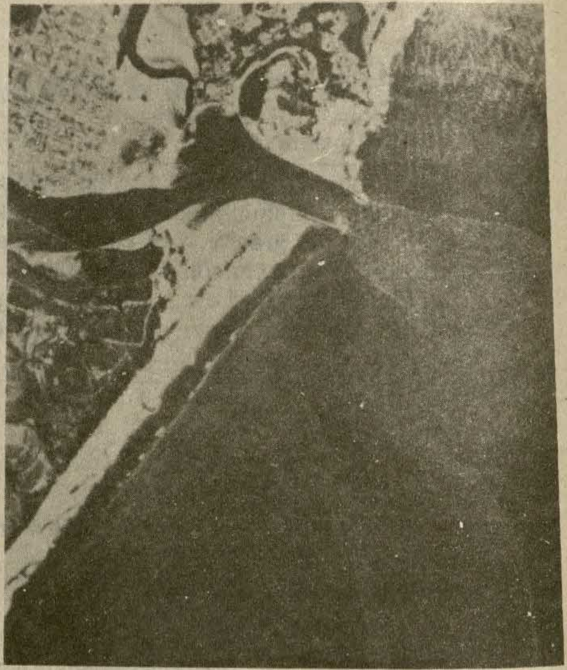


Figure 14.10: New rock in the making. An aerial photograph of the mouth of a river on the north coast of New South Wales. Notice the sediments that have been carried out to sea. These will eventually be compacted into rock. The pattern of streets of a town can be seen in the top left-hand corner. (Photo courtesy N.S.W. Department of Lands)

Table 14.3: Common sedimentary rocks

Mechanically formed rocks	Organically formed rocks
Conglomerate consists of pebble-sized and smaller grains cemented together with sand and clay material.	*Limestone* is usually formed from the remains of marine organisms that secrete calcium carbonate. A finely textured rock that is usually grey to black, it reacts with hydrochloric acid.
Sandstone consists of sand-sized and smaller grains. It is usually white but may be heavily stained with oxides of iron.	*Coal* is formed from plants growing in swamps. As the plants die they fall into the swamp and are changed into peat by the action of bacteria. This peat is changed, by the pressure of sediments on top, first into brown coal and then into black coal.
Shale is a rock containing clay material cemented together. It is usually grey to dark grey in colour, and shows definite banding.	

EXPERIMENT 14.1

Examining the following minerals — quartz, feldspar, hornblende, white mica, black mica and calcite

Each group will need:

- samples of the above minerals
- hand lens
- flat piece of steel
- broken hacksaw blade

What to do

- Copy and complete the following table:

Mineral	Colour and appearance	Diagram of shape of crystal	Diagram showing cleavage planes	Hardness
(a) quartz				
(b) feldspar				
(c) white mica				
(d) black mica				
(e) hornblende				
(f) calcite				

- To help you complete the column about cleavage planes, the following angles are given:
  Mica — parallel cleavage planes
  Feldspar — two cleavage planes approximately at right angles
  Hornblende — two cleavage planes at approximately 60° to each other
  Calcite — three cleavage planes at 75° to one another.
- In order to complete the column headed "Hardness", carry out the following tests:
  - (a) Rub the edge of a piece of quartz along the surface of a piece of steel.
  - (b) Rub the edge of a piece of quartz along the surface of a piece of feldspar.
  - (c) and (d) Rub a piece of feldspar along pieces of mica. Try scratching mica with your fingernail.
  - (e) Try rubbing hornblende with quartz and then with feldspar.
  - (f) Try to scratch calcite with your fingernail and a copper coin.

Questions

14.1 What happens when a drop of dilute hydrochloric acid is placed on top of a calcite crystal?

14.2 Arrange the following minerals in order of hardness from the softest to the hardest: calcite, feldspar, mica, quartz.

EXPERIMENT 14.2

Examining a piece of granite

Each group will need:

- pieces of granite
- hand lens
- materials to test hardness — piece of hacksaw blade, copper coin

What to do

- Copy and complete the following table:

Granite	
Tests done on each mineral	Name of mineral present
1. 2.	
Number of minerals present =	

EXPERIMENT 14.3

Identifying some rocks

Each group will need:

- samples of granite, gabbro, dolerite, rhyolite, pumice, basalt, conglomerate, sandstone, shale and limestone, each specimen carrying a number
- hand lens

What to do

- Examine the rocks. Copy and complete the following table:

Number of specimen	Is rock igneous or sedimentary?	Fine-grained or coarse-grained?	Name of rock
1. 2. 3.			

Questions

14.3 (a) From those examined, name three sedimentary rocks in which fragments can be seen.

(b) Name the one with the largest fragments and the one with the smallest fragments.

(c) How do you explain why some sedimentary rocks have larger fragments in them than others?

14.4 (a) Name two organically formed sedimentary rocks.

(b) Compare the organisms from the remains of which these rocks were formed.

Rocks and minerals

1. Minerals are naturally occurring pure substances.
2. Common minerals are quartz, feldspar, mica, hornblende, calcite and iron oxide.
3. Rocks are naturally occurring solids containing two or more minerals.
4. Igneous rocks are formed when molten mineral solidifies — they may be plutonic or volcanic.
5. Sedimentary rocks are formed from sediments that have hardened — they may be mechanically or organically formed.

Spelling list

appearance
basalt
biotite
calcite
cleavage
conglomerate
dolerite
feldspar
flaky
gabbro
granite
haematite
hornblende
limestone
magma
mica
mineral
muscovite
plane
plutonic
pumice
quartz
rhyolite
solidify

Things to do

14.5 Make a collection of the minerals that can be found in your district. Label each mineral and state where it was found.

14.6 Minerals are often identified by their *streak*. Streak is the colour of the powder from the mineral. To find this colour, scratch the mineral with a file or an industrial diamond. This colour is often different from the colour of the mineral itself. Different samples of a mineral may have different colours but the streak is always the same. Quartz, for example, may be clear, cloudy or smoky but its streak is always white. Test the streak of haematite, limonite, magnetite, hornblende and white and black mica.

14.7 Are you lucky enough to live near an area of exposed igneous rocks — a quarry perhaps? Plan an excursion to the area. Wear old shoes and take a rucksack, geological hammer, hand lens, penknife, file and notebook. Collect and identify rock specimens. Find out the history of the formation of the rocks.

More questions

14.8 Are there any stone buildings in your district? What rock was used in each building? Can you find out where it came from?

14.9 What kind of rock is beneath your school? Has the area ever been covered by the sea? Ask your teacher to tell you the age of these rocks.

14.10 Would you classify ice as a mineral? Have a class discussion on the subject.

Test yourself (chapter 14)

Write the answers to the following in your workbook:

1. The different substances in a rock are called ____________.
2. What is the general name given to rocks formed by the crystallization of molten material?
3. Name the hardest mineral in granite.
4. Name a dark mineral almost as hard as feldspar.
5. From the list of minerals in the right-hand column, choose the one that best fits each of the descriptions in the left-hand column.

(a) very hard, no cleavage	haematite
(b) light-coloured, three cleavage planes at 75°	quartz
(c) light-coloured, two cleavage planes almost at right angles	calcite
	feldspar
(d) dark, two cleavage planes at about 60°	hornblende
(e) very soft, flakes into sheets	mica

In each of the questions 6 – 10, choose the best answer and write its letter in your workbook:

6. Granite is a rock
   - (a) containing crystals big enough to see
   - (b) made up of mostly dark minerals
   - (c) formed by the cooling of a lava flow
   - (d) made up of layers of different colours.
7. Basalt
   - (a) is a sedimentary rock
   - (b) is formed by slow cooling
   - (c) is formed in lakes
   - (d) consists of tiny crystals.
8. A rock is found that contains many rounded grains about 3 millimetres across. Of the alternatives listed below, the only rock it could be is
   - (a) granite
   - (b) feldspar
   - (c) conglomerate
   - (d) basalt.

9. A rock formed from living things is
   (a) sandstone
   (b) limestone
   (c) shale
   (d) conglomerate.
10. Basalt is
    (a) volcanic and light in colour
    (b) plutonic and light in colour
    (c) volcanic and dark in colour
    (d) plutonic and dark in colour.

15

Weathering and erosion

Figure 15.1 is a photograph of a road cutting. Notice the changes from the bottom to the top of the cutting — solid rock at the bottom, soil at the top. It is apparent that long ago the top must have been solid rock also, but something has broken it up into fragments. This something is the process called weathering.

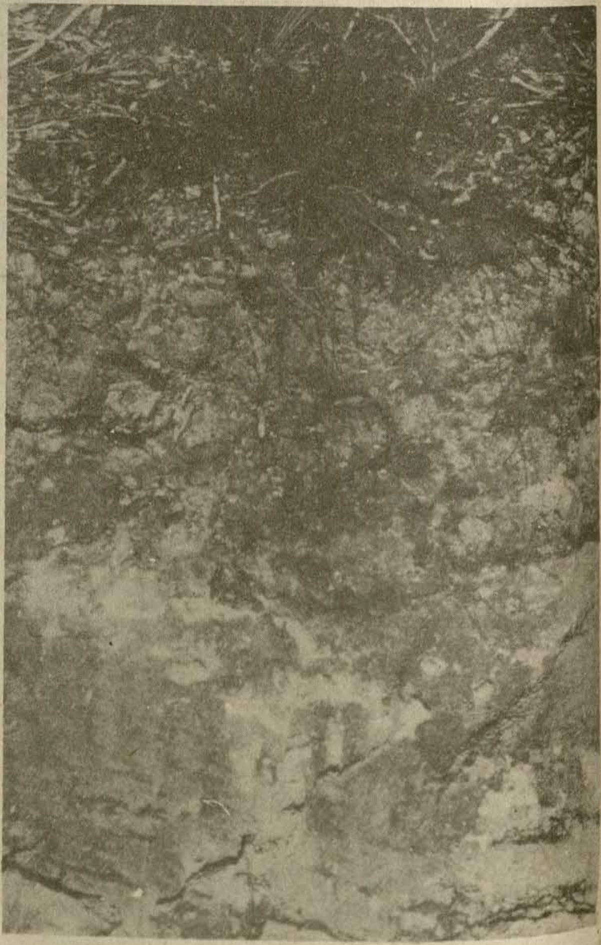


Figure 15.1: A photo taken in a road cutting showing soil at the top and solid rock at the bottom. A long time ago the top must have been solid rock too, but it has been broken up by a process called weathering.

Weathering

Weathering may be either mechanical or chemical. In mechanical weathering the rock is split up into smaller pieces without any new substances being formed. In chemical weathering the rock is actually changed into new substances by chemical action. Most rocks undergo both mechanical and chemical weathering at the same time.

The removal of the weathered material is called *erosion*. Erosion will be considered further on page 166.

Mechanical weathering

Mechanical weathering is the result of one or more of the following:

Daily variation in temperature. Weathering in arid regions is largely due to the great difference between day and night temperatures. Intensely heated during

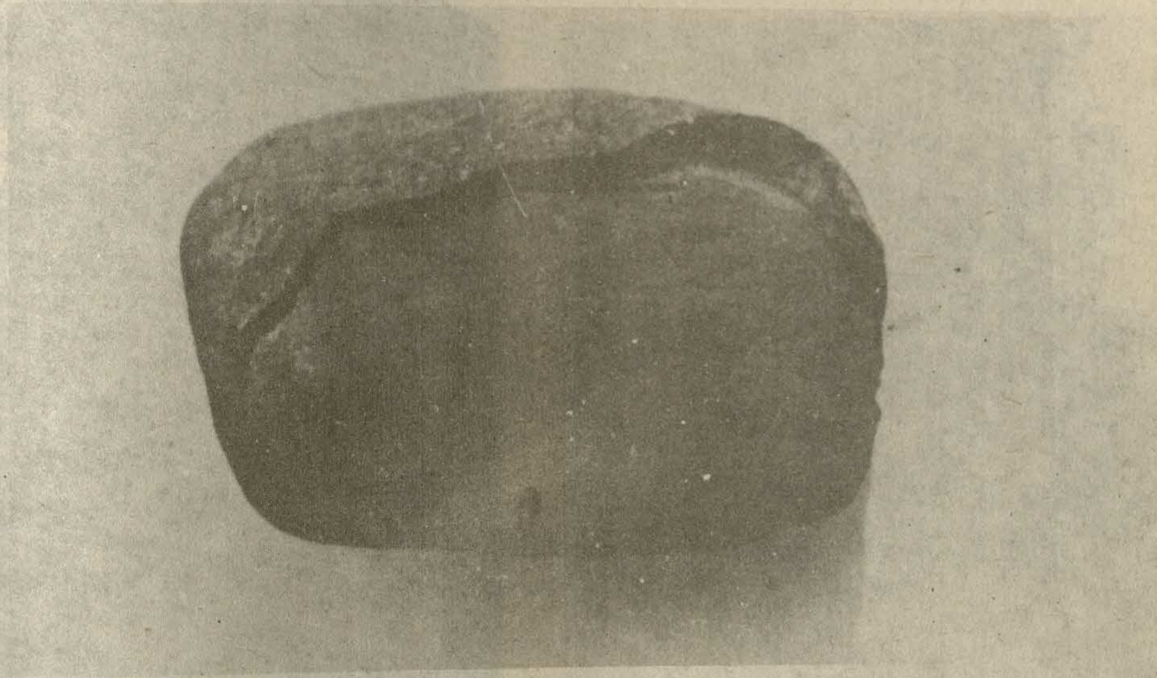


Figure 15.2: Rock showing spalling due to daily variation in temperature.

the day, the outer layers of the rock expand and tend to pull away from the cooler central mass. At night these outer layers lose heat and contract; this may cause more cracks to develop. In this way flakes are gradually broken off the main rock. These flakes are called *spalls.*

Frost shattering. Water may seep into cracks and crevices in rocks. If this water freezes it expands and tremendous forces may act — as much as 200 kilograms on every square centimetre of rock surface resisting the expansion. This force weakens the rock and may eventually shatter it. This process is called frost shattering; it is very common on exposed mountain slopes in cold regions.

The action of water on clay. Clay expands when wet and shrinks when it dries out. Cracks sometimes appear in brick houses built on clay because of this.

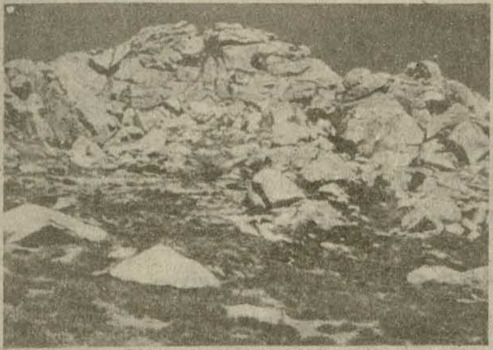


Figure 15.3: Rocks shattered by frost on the Ramshead Range, near Mount Kosciusko.

Sandstone is a rock consisting of hard sand grains usually cemented together with clay. Sandstone exposed to alternating wet and dry conditions will weather. The expansion when wet followed by the contraction when dry

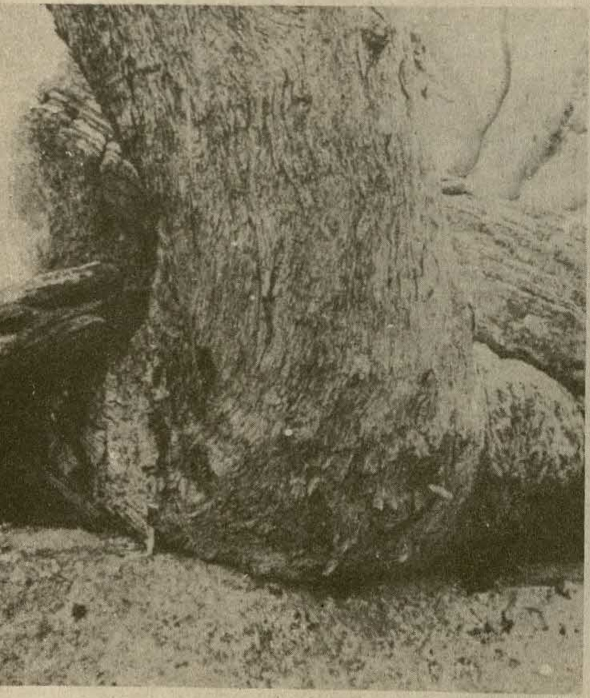


Figure 15.4: A mass of rock being broken by the roots of a tree.

results in the clay wedging out the hard sand grains, thus breaking down the rock.

The action of living things. Figure 15.4 is a photo of a boulder that has been split in two by the roots of a tree.

Chemical weathering

Most chemical weathering is due to the action of rainwater, which contains gases dissolved from the atmosphere.

Water and dissolved carbon dioxide. Water containing carbon dioxide will dissolve limestone. Figure 15.5 shows a huge limestone cavern formed by the dissolving action of this kind of water.

Limestone is mainly calcium carbonate. Marble and chalk are rocks that also contain calcium carbonate, and these are dissolved in the same way by water containing carbon dioxide.

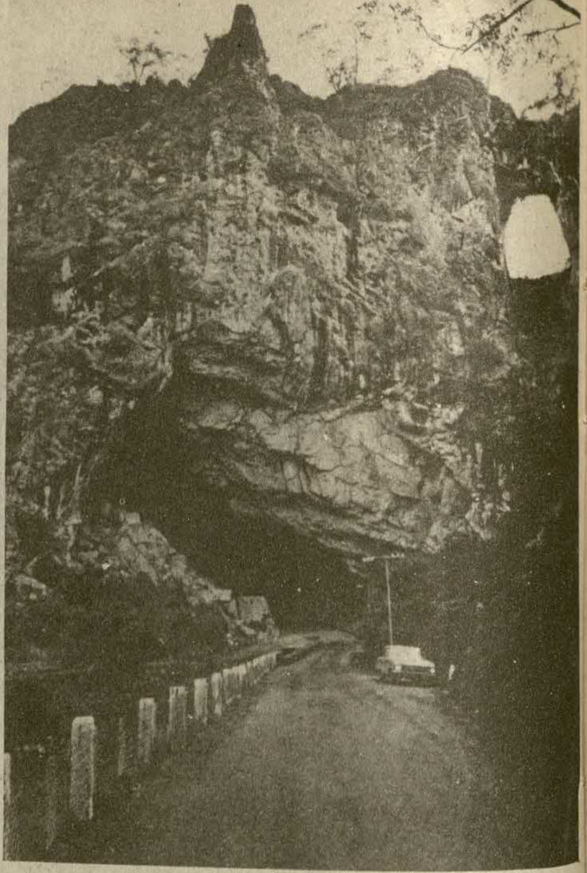


Figure 15.5: The Grand Arch, Jenolan Caves, New South Wales, spans a huge cavern formed by the dissolving action of water containing carbon dioxide on limestone. (Photo courtesy N.S.W. Department of Tourism)

Some rocks are altered by water containing carbon dioxide but are not dissolved by it. Granite is such a rock. Granite contains quartz, feldspar and some dark minerals. The feldspars and dark minerals weather to form clay, whereas the quartz resists weathering.

Igneous rocks often contain cooling cracks. Water may seep into these cracks and weather the rock in the manner described above. Figure 15.6 shows how granite boulders may be formed by this action. These boulders are called tors. Figure 15.7 is a photograph of granite tors in New England, New South Wales.

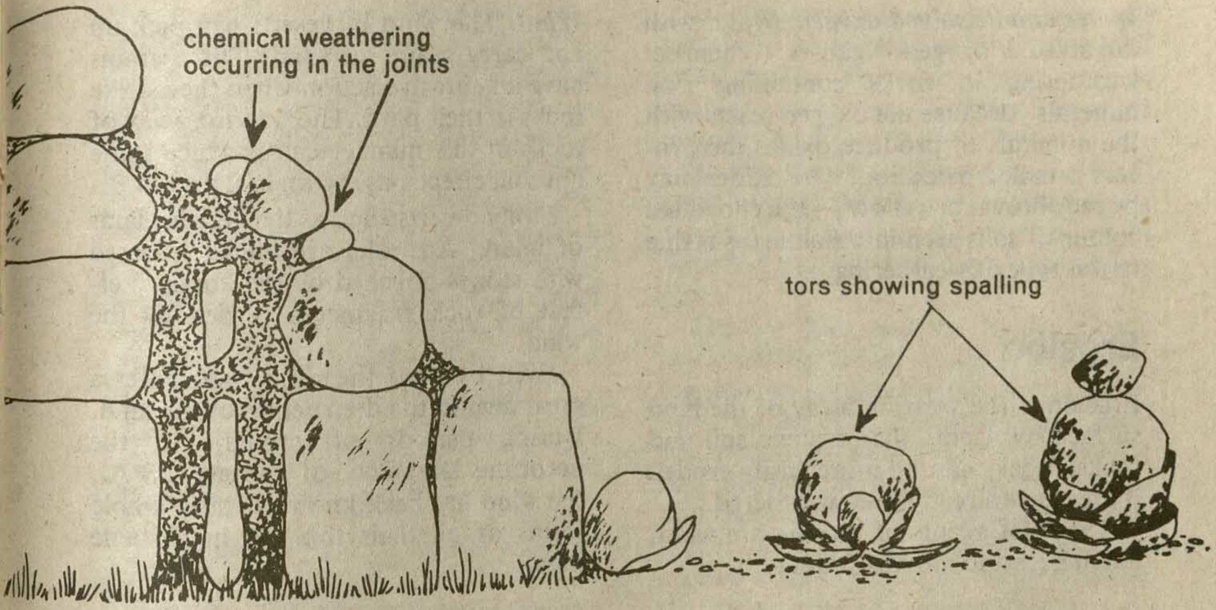


Figure 15.6: Diagram showing how granite tors are formed.

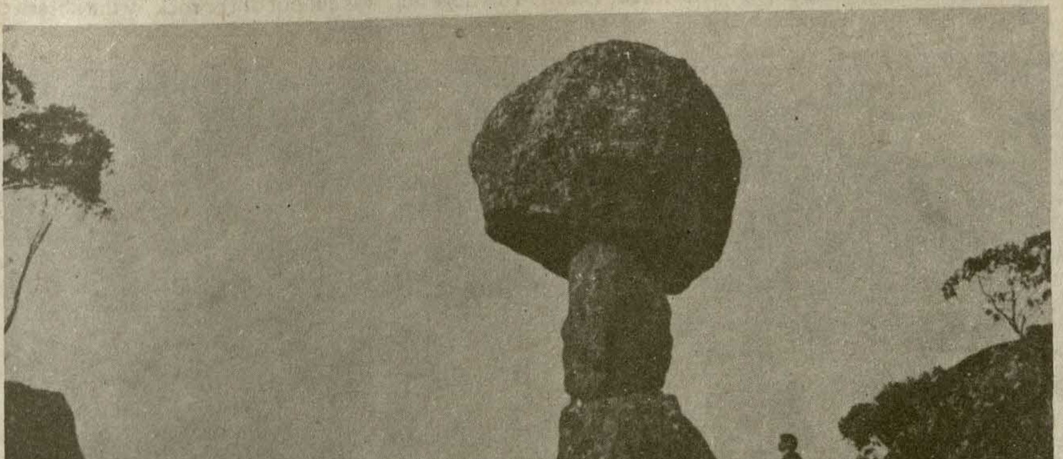


Figure 15.7: Granite tors, New England, New South Wales. (Photo courtesy N.S.W. Department of Tourism)

Water and dissolved oxygen. Water with dissolved oxygen causes chemical weathering in rocks containing iron minerals. Because the oxygen reacts with the minerals to produce oxides the process is called oxidation. The oxides may be red, brown or yellow — the chocolate colour of soils seen in basalt areas is due to this type of weathering.

Erosion

Erosion is the wearing away of the land surface by agents that remove soil and rocks. Rocks can be more easily eroded if they have already been weathered.

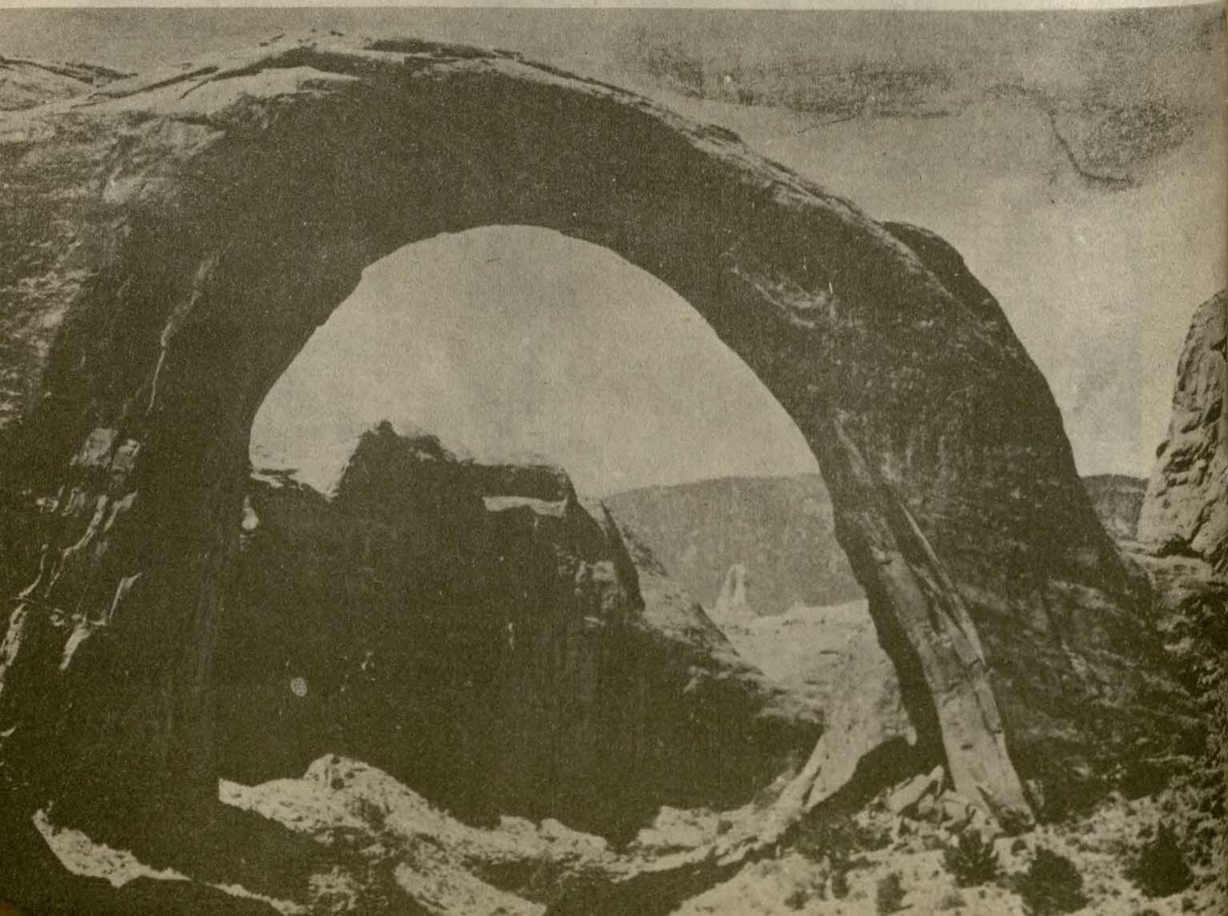
The chief agents of erosion are wind, moving ice and moving water.

Wind. The wind in deserts can pick up and carry grains of sand. These grains have an abrasive action when they strike rocks in their path. The wearing away of rocks in this manner can produce some unusual effects, as shown in figure 15.8.

Stony deserts such as the gibber plains of inland Australia are thickly covered with stones polished by the abrasive effect of rock fragments carried by the wind.

Even by itself the wind contributes a great deal to the destruction of the land. During periods of drought in the notorious Dust Bowl of Kansas, U.S.A., the wind has been known to strip whole farms of all their top soil in a single night.

Figure 15.8: Looking Glass Rock, Colorado, U.S.A. This huge hole was cut out of the rock by the abrasive action of wind-blown sand.



Moving water. The chief agent of erosion is running water. The ability of running water to carry rock debris depends on its speed. Doubling the speed of running water increases its carrying power about sixty times. The main factor, therefore, in protecting soil against erosion is to prevent surface water getting up speed. Vegetation will obviously reduce the speed of surface water. Figure 15.9 shows the effects of erosion on land that has been stripped of vegetation.

Figure 15.10 shows a paddock on gently sloping ground that has been ploughed along the contours to decrease the speed of surface water.

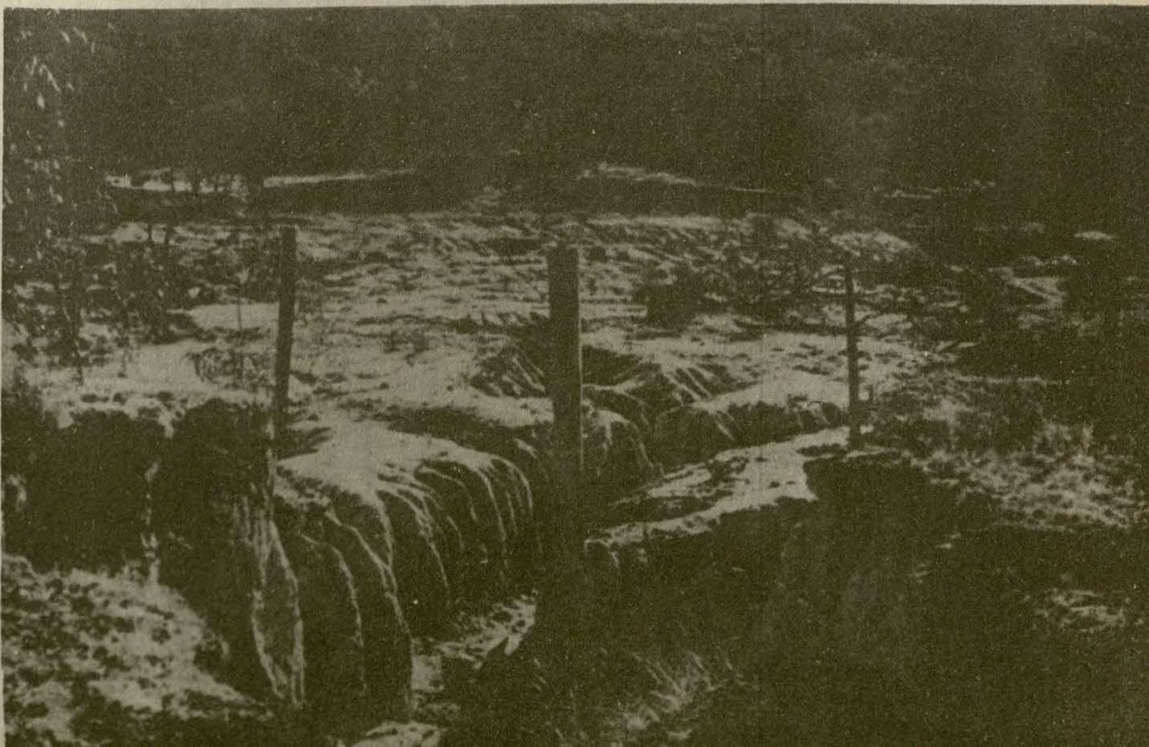
Rivers and creeks carry three kinds of debris:

- boulders and pebbles rolled along the river bed
- mud, silt and sand in suspension in the moving water
- material in solution.

Slow-moving streams carry little else but dissolved material and very fine mud in suspension. The main erosive work of running water must therefore be done during periods of flood. Even so, one does not see vast changes in the landscape during a lifetime. The cutting of a deep valley, such as the one shown in figure 15.11, takes at least five million years.

The sea does most of its destructive work during storms. Huge waves carrying sand and pebbles bombard the shore. Most of the force is directed at a zone just above sea level. Here the shoreline may become undercut. You have probably noticed that cliffs tend to jut out higher up, the lower parts having been eroded away. Gravity eventually causes the collapse of the overhanging part of the cliff. The gradual falling back of the shoreline due to this type of erosion leaves a rock platform just below the sea level.

Figure 15.9: Deep gully erosion of land stripped of natural vegetation. (Photo courtesy N.S.W. Government Printer)



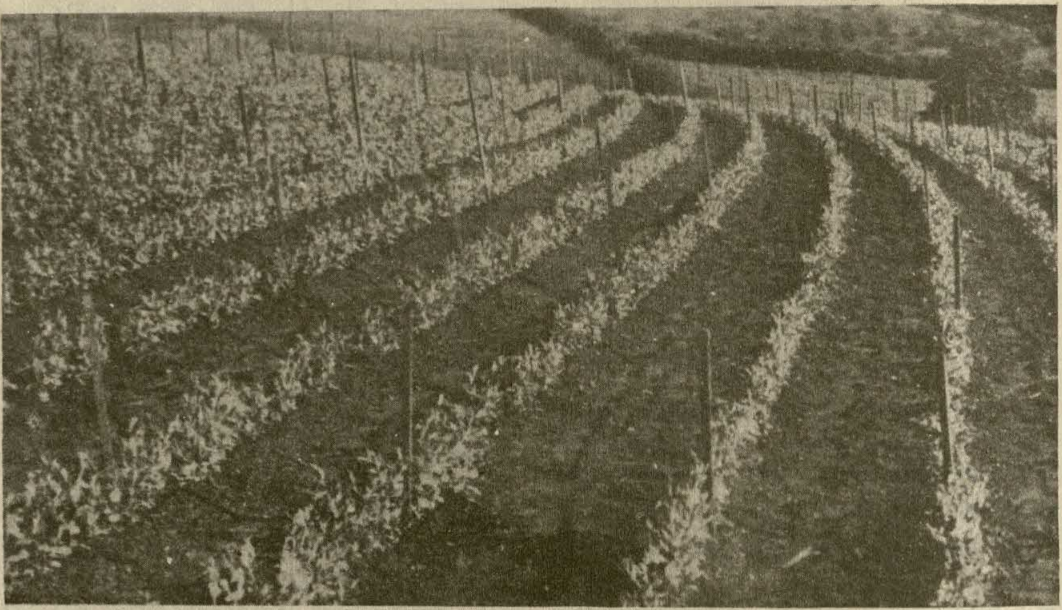
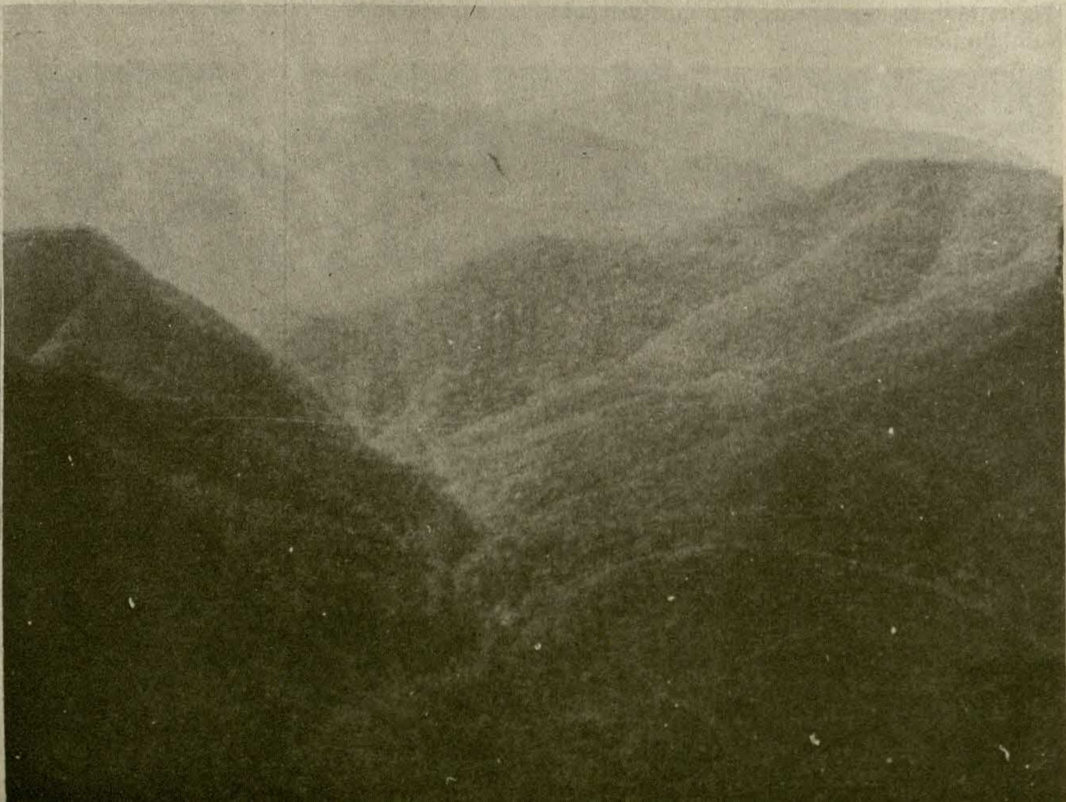


Figure 15.10: A paddock ploughed along the contours to decrease the speed of surface water. (Photo courtesy N.S.W. Government Printer)

Figure 15.11: Upper Kanangra River. Note the V-shaped gorge typical of the upper courses of a river.



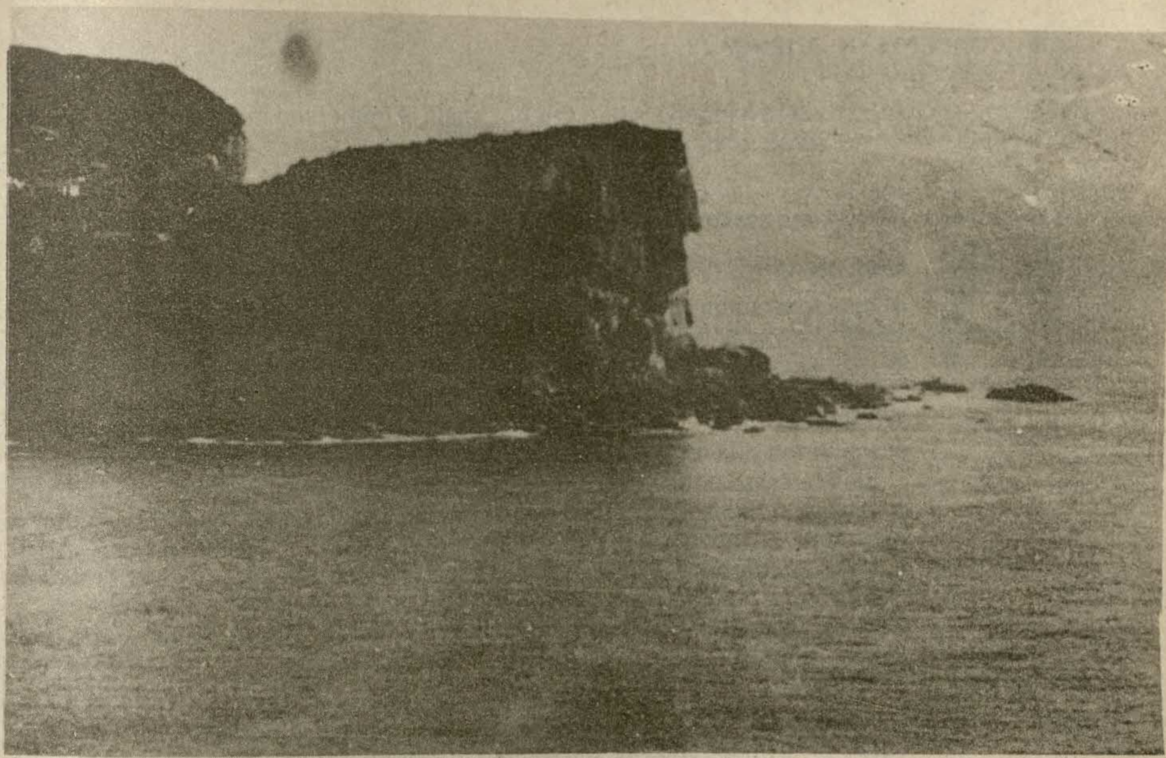


Figure 15.12: A cliff showing undercutting at the shore line, Avalon, New South Wales

Ice. It may seem strange that moving ice can erode rock that is much harder than itself. Most of the erosion is due to the grinding action of boulders and pebbles that are gripped firmly by the ice. A moving glacier is like a giant piece of sandpaper with the ability to smooth and deepen the valleys through which it passes.

The signs of glacial erosion differ from those of erosion by running water. Rivers form V-shaped valleys whereas glaciers form U-shaped valleys, whose sides may be almost vertical.

EXPERIMENT

15.1

What happens when a piece of shale is heated strongly?

Each group will need:

- tripod
- pipeclay triangle
- pair of tongs
- Bunsen burner
- piece of shale
- beaker of water

What to do

- Place the piece of shale on the pipeclay triangle on a tripod.
- Heat it strongly with a Bunsen burner.

Questions

15.1 Did the shale split? If it did, can you explain what happened by assuming the rock expanded when heated?

15.2 Wnat happens when the hot shale is immersed in cold water? Try the effect of heating and cooling other rocks.

EXPERIMENT 15.2

What happens to wet clay when it dries?

Each group will need:

- clay (preferably potter's clay)
- clock glass or large tin lid
- plastic dish

What to do

- Place the clay in a plastic dish. Add water a little at a time and work the clay by hand until it becomes a plastic mass.
- Spread some of the moist clay thinly on a clock glass or tin lid so that it completely covers the glass or lid.
- Place the glass or lid in a sunny position and observe it daily until it is thoroughly dry.
- Moisten the clay very gradually and observe the effect of the water over several hours.

Questions

15.3 What happened to the moist clay when it dried out? What happened when the clay was moistened?

15.4 Many kinds of sandstone consist of quartz particles cemented together by clay under pressure. What could be the effect of alternately wetting and drying sandstone rock?

EXPERIMENT 15.3

By how much does the carrying power of water increase when the speed of the water is doubled?

Each group will need:

- a number of smooth round pebbles
- garden hose
- house brick
- balance
- stopwatch

What to do

- Choose some pebbles with the diameters shown in figure 15.13.

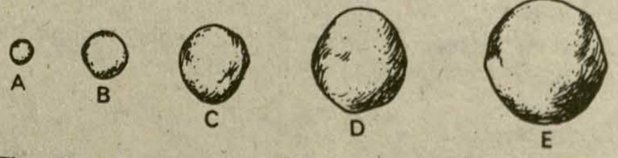


Figure 15.13: The diameters of these pebbles are approximately 3, 6, 9, 12 and 15 millimetres respectively.

- Direct a stream of water from a hose into a gutter, anchoring the hose with a house brick so that it does not move.
- Adjust the flow so that when pebble A is placed in the stream it will just move or move very slowly. Put the pebble in the stream at least one metre away from the hose nozzle to reduce turbulence.
- Put a match in the stream and see how far it moves in 10 seconds. Record this distance in centimetres.
- Turn up the hose, adjusting the flow until a match put in the stream moves twice as far in 10 seconds as in the previous case.
- Place pebbles B, C, D and E in turn in the stream and choose the pebble that just moves or moves very slowly.
- Weigh the pebble chosen and also weigh pebble A.

Questions

15.5 How many times heavier was the second pebble than pebble A?

15.6 What do you think is the main wearing agent in a stream — the water itself or the sand and gravel carried by the water?

Weathering and erosion

1. Weathering is the breaking down of rocks of the earth's crust.
2. Physical weathering may be due to
    - the daily temperature variations
    - frost shattering
    - the action of water on clay
    - the action of living things.
3. Chemical weathering is due to the action of
    - dissolved carbon dioxide in rainwater
    - dissolved oxygen in rainwater.
4. Erosion is the wearing away of the land surface by agents that remove soil and rock.
5. The chief agents of erosion are
    - moving water
    - wind
    - moving ice.

Spelling list

abrasive
boulder
contour
erosion
glacier
pebble
spall
tor
variation
weathering

Things to do

15.7 Limestone and marble are both mostly calcium carbonate. Try the effect of carbon dioxide on calcium carbonate by bubbling the gas through a suspension of calcium carbonate powder in water in a test tube. Prepare the suspension by grinding some of the powder with water in a mortar.

You will find that the suspension of chalk slowly dissolves. In nature the action is very slow indeed. For example, it took millions of years for the carbon dioxide in rainwater to carve out the hole shown in figure 15.5.

15.8 Basalt often shows "onion" weathering. If you visit basalt areas, look for rocks from which thin layers have peeled off like skin off an onion. Basalt weathers to form clay. It is the effect of alternate wetting and drying of the clay that causes the peeling.

15.9 Compare a piece of freshly broken granite with a piece of weathered granite. Notice how hard the first is and how easy it is to break up the second. What does granite form as it weathers?

15.10 Basalt is a bluish-black rock. What then is the cause of the dark brown soils in basalt areas? They are caused by the action of oxygen on the iron minerals in the basalt. You can carry out an experiment in the laboratory to show a related change in colour. Dissolve some green iron sulphate in some water in a beaker. Either bubble oxygen through the water or add hydrogen peroxide. (Hydrogen peroxide is rich in oxygen.) Note the change in colour.

More questions

15.11 Is there any erosion in your school playing area or in nearby open areas? Do you think it can be prevented? How?

15.12 By a series of diagrams, show the various stages leading to the rock formation shown in figure 15.7.

15.13 What are fiords and how are they formed?

15.14 Figure 15.14 is a photograph of the Breadknife, in the Warrumbungle Mountains of New South Wales. The formation is only two or three metres thick. Try to find out how such a thin formation occurs and why it has remained standing while the surrounding rock has been eroded away.

Test yourself (chapter 15)

Write the answers to the following in your workbook:

1. Name the substance of which limestone is mostly composed.
2. Name the main agent of erosion.

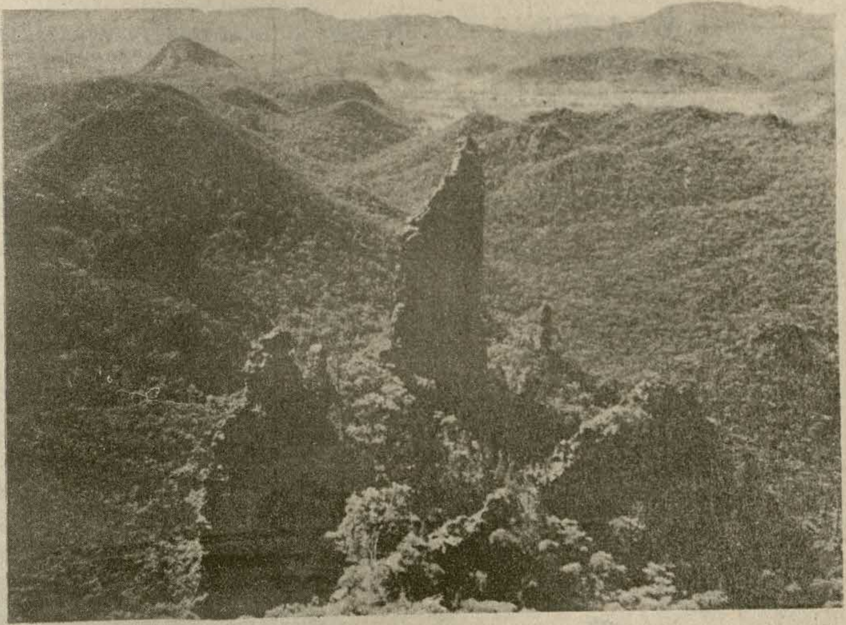


Figure 15.14: The Breadknife, Warrumbungle Mountains, New South Wales. (Photo courtesy N.S.W. Department of Tourism)

3. Complete each of the following sentences by using one of the words in the right-hand column.

(a) Rocks __________ because of variation in temperature. (b) The feldspar and the dark minerals in granite weather to form __________. (c) __________ shrinks when it dries. (d) Cracked rocks split when __________ forms in the cracks.	gravel melt basalt spall clay soil water quartz ice

In questions 4 to 6 choose the best answer and write its letter in your workbook.

4. The substance present in rainwater that enables it to dissolve limestone is
   - (a) carbon dioxide
   - (b) oxygen
   - (c) salt
   - (d) nitrogen.

5. Wind erosion is most effective in those regions where the climate is
   (a) cold
   (b) humid
   (c) dry
   (d) hot.

6. The land form in figure 15.15 has been produced mainly by the action of
   (a) water
   (b) ice
   (c) wind
   (d) volcanoes.

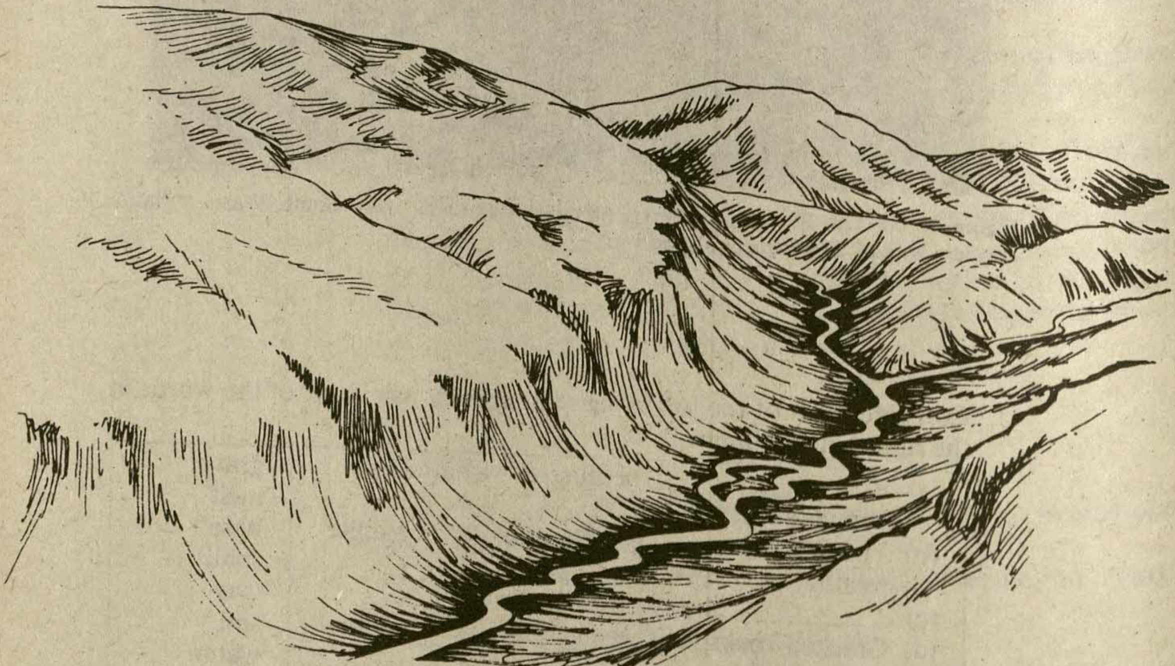


Figure 15.15

16

Light

Light is one of the most important forms of energy. Without light, life as we know it on Earth would not exist.

Light enables us to see; it is the main form of energy by which we can explore the things around us.

Two thousand years ago ideas about light were confused because thinkers did not understand the difference between light and vision. Some philosophers thought that visible objects gave off tiny particles that were minute replicas of the object from which they came. Others thought the eyes emitted a steady stream of light that, when it collided with an obstructing object, caused this object to be seen.

Even today scientists do not completely understand everything about light.

In this chapter we shall study some aspects of this form of energy.

Emission of light

In chapter 10 we showed that light is produced when a metal is heated. As the temperature rises, the light emitted is first red, then orange, yellow, white and finally blue-white. All solids emit light if heated to a sufficiently high temperature.

Liquids and gases also give off light if the temperature is high enough. For example, it is possible to heat some common salt in a crucible until it melts and glows, giving out red light. Fluorescent lights are columns of gas heated by electrical energy.

Many flames give off light because they contain hot particles of matter. In the flame of a candle, for example, the light is given out by hot particles of carbon.

Transparent and opaque materials

Many substances, such as air, water, colourless glass and plastics, allow light to pass through with very little absorption. Some absorption occurs nevertheless. For example, several hundred metres down in the ocean it is almost completely dark — the water has absorbed almost all the light.

Most substances are opaque to light, that is, light can be absorbed or reflected by them. In most cases both absorption and reflection occur at the same time. Hold up pieces of different-coloured materials in front of a light meter on a camera. A high reading on the meter indicates a lot of reflection with little absorption. A low reading indicates little reflection and a lot of absorption. In one particular experiment, the meter was placed eight centimetres in front of various pieces of coloured cloth, with the following results:

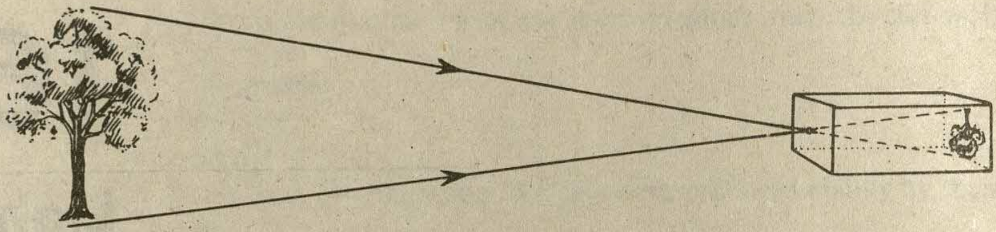


Figure 16.1: The pinhole camera. The light rays pass through the small hole and an inverted image of the tree appears on the back of the box.

Colour of cloth	Reading on light meter
white	8 units
red	4 units
blue	4 units
black	½ unit

From these results it appears that a white surface reflects most light and a black surface least.

Light travels in straight lines

Beams from searchlights and headlights on foggy nights have edges that are straight. When he uses his theodolite, the surveyor makes use of the fact that light travels in straight lines.

The simple pinhole camera gives further evidence of this fact. (See figure 16.1.)

The image on the screen at the back of the camera is upside-down and its position is such that the top of the tree, the pinhole, and the bottom of the image are all in the one straight line.

Shadows

Because light travels in straight lines it casts shadows when it strikes opaque objects. A point of light, such as a torch globe, casts a sharp shadow, whereas an area of light, such as a pearl electric light globe, casts a shadow with blurred edges. (See figures 16.2a and 16.2b.)

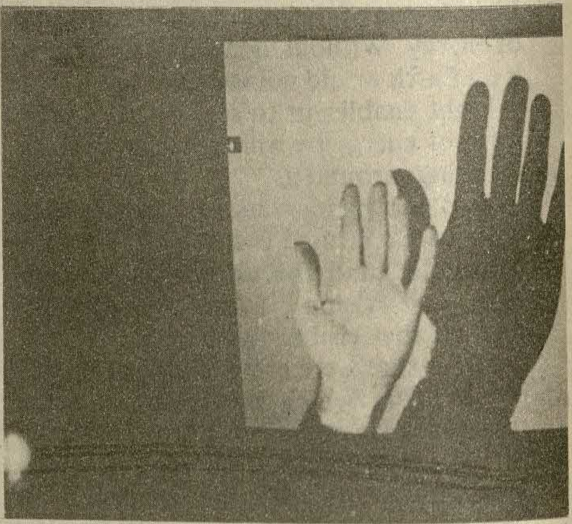
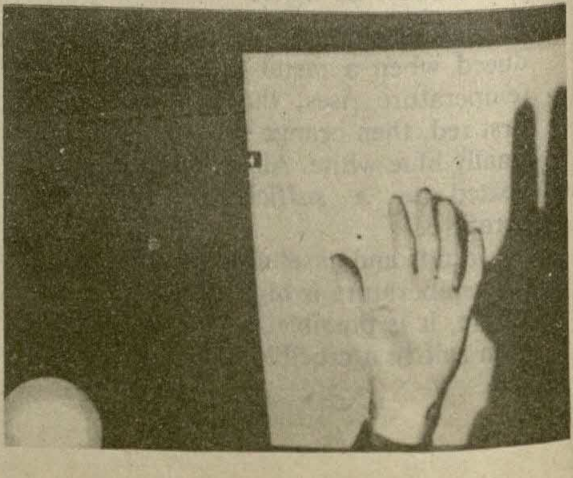


Figure 16.2(a): A shadow with sharp edges. Such a shadow is cast by a point of light, such as a torch bulb. Notice the shadows of the hairs on the wrist.

Figure 16.2(b): A shadow with blurred edges. Such a shadow is cast by a large light source, such as a pearl electric light bulb.



The blurred edge of the shadow, the area between full shadow and full light, is called the penumbra. The area of full shadow is called the umbra.

Eclipse of the sun

The sun is not a point but an area of light and therefore does not cast sharp shadows. This is illustrated during an eclipse of the sun, when the moon casts a shadow on the earth. The zone of full shadow (umbra) is a circle of darkness, often not more than 150 kilometres across, whereas the penumbra extends a much greater distance. (See figure 16.3.)

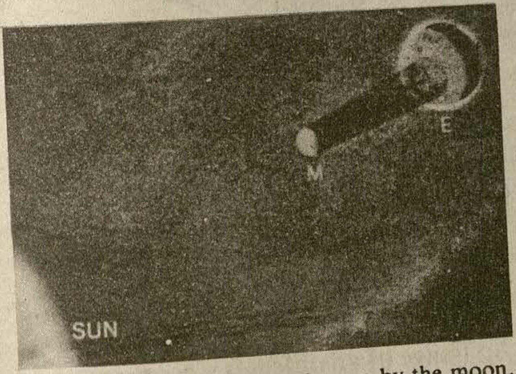


Figure 16.3: An eclipse of the sun by the moon. (On this scale the sun should be very much further away than is shown in the diagram.) The cover photograph also shows an eclipse of the sun.

Beams

In future discussions about light we shall be referring to beams. There are three kinds of beams — parallel beams, diverging beams and converging beams. These are illustrated in figure 16.4.

The point to which a beam converges is the focus. After passing through the focus, the beam diverges.

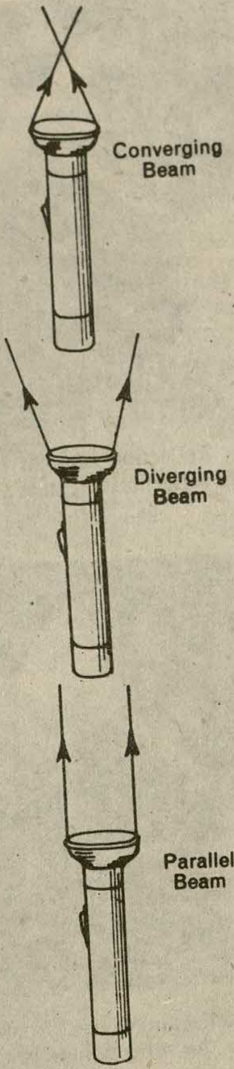


Figure 16.4: Three kinds of beams of light.

Reflection

Reflection occurs all around us. Because of reflection of sunlight from objects outside, our houses do not need electric light during the day. Most things are visible to us because they reflect light to our eyes.

Both smooth and rough surfaces reflect light, but from smooth surfaces the reflection is regular, whereas from rough surfaces it is irregular. (See figures 16.5a and 16.5b.)

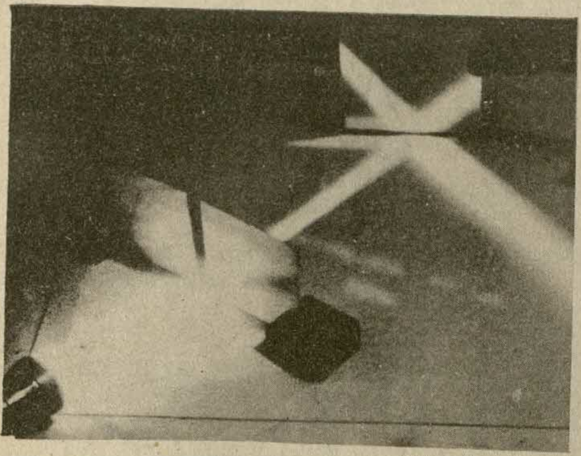


Figure 16.5(a): Reflection of light from a glass mirror. Here the reflection is regular.

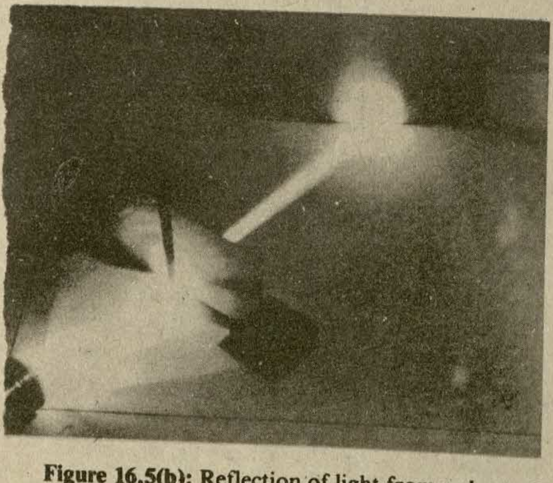


Figure 16.5(b): Reflection of light from a sheet of cardboard. Here the reflection is irregular; the light is scattered.

When we think of a mirror as a smooth surface, we must remember that it is not the glass that reflects the light but the silver or aluminium coating on the back of the glass. The glass merely supports and protects the metal coating.

The law of reflection

When a billiard ball strikes the side of a billiard table it bounces off at the same angle as that at which it struck. This is true of all cases of reflection — the angle of reflection is equal to the angle of striking. A generalization such as this is called a *law*. The law of reflection states that the angle of reflection equals the angle of incidence. (See figure 16.6.)

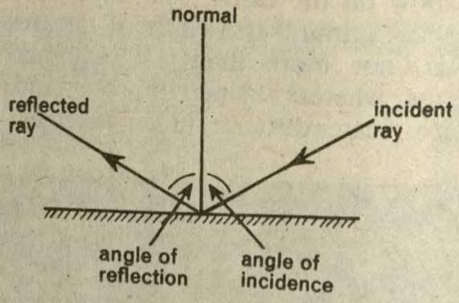


Figure 16.6: The law of reflection. The angle of reflection equals the angle of incidence.

Images

An image of an object is a counterpart of it. Images may be larger (magnified), or smaller, or the same size as the object.

An object when viewed directly is seen because rays of light travel from the object to the eye. (See figure 16.7a.)

Figure 16.7b shows how a plane mirror merely changes the direction of the diverging beam so that it appears to come from behind the mirror and not from the object itself. Although the object is in front of the mirror, the eye sees it as apparently behind the mirror.

Such an image as this is called a virtual image. It cannot be placed on a screen. Images that can be placed on a screen are called real images. You see real images, for example, when you go to a theatre to watch a film.

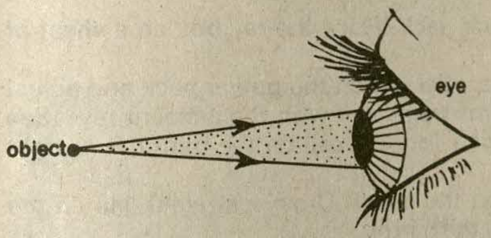


Figure 16.7(a): Viewing an object directly.

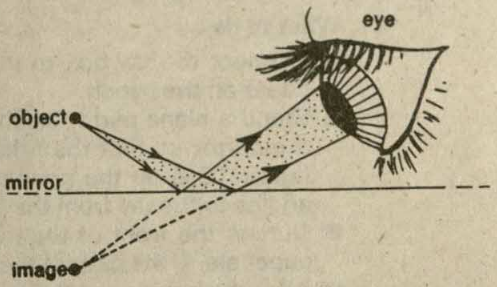


Figure 16.7(b): Viewing a virtual image of the object. The object is seen because of reflection of light off the surface of the mirror.

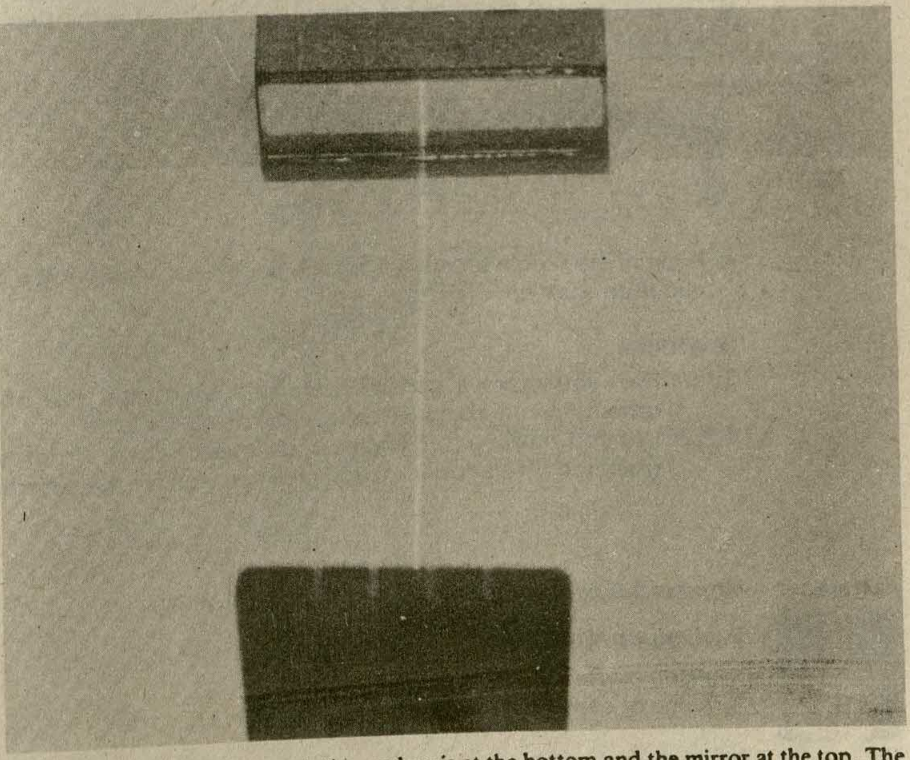


Figure 16.8: In this photograph the ray box is at the bottom and the mirror at the top. The mirror has been positioned so that the ray it reflects coincides with the incident ray coming from the box.

EXPERIMENT

16.1

What happens to light rays when they are reflected from mirrors?

Each group will need:

- ray box
- power pack
- sheet of white paper
- plane, convex and concave mirrors
- protractor

What to do

- Connect the ray box to the power pack. Place the ray box on a sheet of paper on the bench.
- Stand a plane mirror on the paper. Switch on the power pack and adjust the mirror so that the reflected ray coincides with the incident ray. (See figure 16.8 on the previous page.) In this position the mirror is at right angles to the ray from the box.
- Outline the front of the mirror on the paper. Draw a straight line on the paper along the path of the ray to the mirror.
- Alter the position of the ray box so that the ray strikes the mirror obliquely but at the same point on the mirror as the previous ray.
- Draw in the incident ray and reflected ray and measure the angles of incidence and reflection.
- Do this several times to get a number of values for the two angles. Copy and complete the following table:

Type of mirror	Angle of incidence	Angle of reflection
Plane		

- Repeat the whole process from the beginning, using first a convex mirror and then a concave mirror.

Questions

16.1 Can you make a general statement about the size of the angle of reflection compared with the angle of incidence?

16.2 Did you find the two angles equal in each case? If not, what was the greatest difference? Can you give a reason for the difference?

EXPERIMENT

16.2

What is the nature of the image in a plane mirror?

Each group will need:

- plane mirror
- piece of cardboard

What to do

- Print "I WILL SEEK" on the cardboard, using letters sloping to the right.
- Hold the cardboard in front of the mirror so that you see an image of the words in the mirror.

Questions

16.3 Did you notice that the printing is reversed right to left and that the letters slope to the left? We say the image is *laterally reversed*.

16.4 Look at yourself in a mirror. Raise your right hand. Can you see that your image raises its left hand?

16.5 Have a competition to print the longest word of which the image is the same as the original. You will have to use letters such as A, H, I, and so on.

EXPERIMENT

16.3

Where is the image formed by a plane mirror?

Each group will need:

- plane mirror
- two pencils or knitting needles stuck into corks.

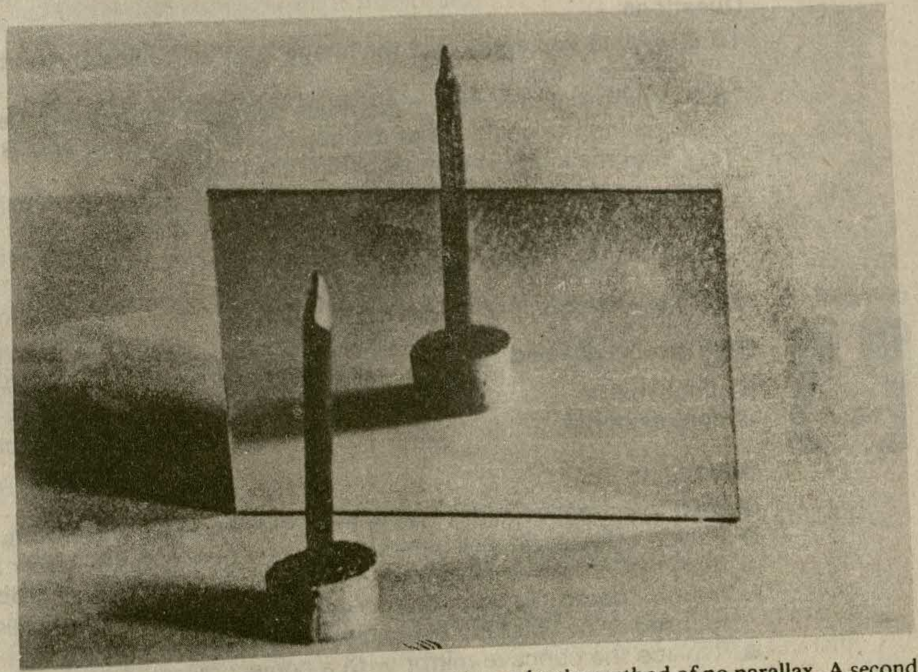


Figure 16.9: Finding the position of a virtual image by the method of no parallax. A second pencil is positioned behind the mirror so that it appears to be in the same position as the image of the first pencil.

What to do

- Stand a pencil vertically in front of a plane mirror, as shown in figure 16.9.
- Take a second pencil and place it behind the mirror so that it appears to be standing on top of the image of the first pencil.
- Move your head from side to side and at the same time move the second pencil backwards and forwards until it appears to stand on top of the image of the first, no matter from what angle it is viewed. The second pencil is now in the position of the image of the first pencil. This is called the *method of no parallax*.
- Measure the distance from the object to the back of the mirror and from the back of the mirror to the position of the image. Remember that reflection takes place on the silver on the back of the glass.

- Repeat the experiment a number of times. Copy and complete the following table:

Distance from object to reflecting surface	Distance from reflecting surface to image

- Measure the angle between the mirror face and the line joining the object and the position of the image.

Questions

16.6 Would you agree that the image is as far behind the mirror as the object is in front?

16.7 What was the size of the angle between the mirror face and the line joining the positions of the object and image? If it was 90°, it means that the image is directly behind the mirror.

EXPERIMENT 16.4

Real and virtual images

Each group will need:

- plane mirror
- convex mirror
- concave mirror
- small sheet of white cardboard

What to do

- Hold the concave mirror facing the windows of the classroom.
- Position the cardboard between the windows and the mirror so that light from the windows is reflected from the mirror on to the cardboard. Move the cardboard about until you get a clear image of the window frames focused on it. This kind of image is called a real image.
- Replace the concave mirror with a convex mirror. Try to get a real image of the window on the cardboard using this mirror.
- Repeat, using the plane mirror.

Question

16.8 Did you focus images on the cardboard using the convex mirror and the plane mirror? If you did not, it would appear that these two kinds of mirrors do not form real images. They form only virtual images, which appear to be behind the mirror.

Light

1. Light may be emitted by heated matter.
2. Light travels in straight lines.
3. Light is reflected or absorbed by opaque surfaces.
4. When light is reflected, the angle of incidence is equal to the angle of reflection.
5. Points of light cast sharp shadows.
6. Lights larger than points cast shadows with blurred edges.
7. The images seen in a plane mirror are:
   - virtual
   - laterally reversed
   - as far behind the mirror as the object is in front.

Spelling list

absorption
camera
concave
converging
convex
diverging
eclipse
emission
incidence
laterally
parallax
penumbra
plane
reflection
umbra
virtual

Things to do

16.9 Can you see around two corners? Set up two plane mirrors at adjacent corners of a rectangular box so that you can see the side of the box opposite to the side you are on.

16.10 Make a periscope, using two small plane mirrors and a piece of cardboard about 40 cm by 25 cm. Use Sellotape to make the tube and to hold the mirrors in position.

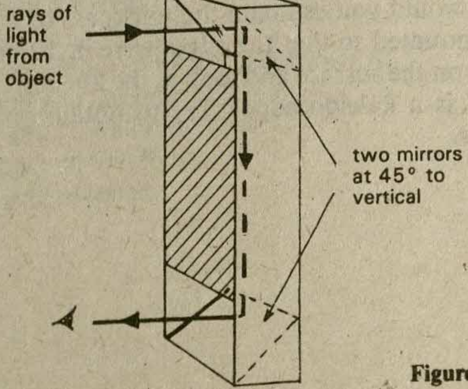


Figure 16.10: Model periscope.

16.11 Write your name on a piece of paper with carbon paper underneath, face upwards. Look at the carbon impression of your name on the back of the paper. Now look at the impression's reflection in a plane mirror.

16.12 How well can you read print with a mirror? Have a competition. Use a stopwatch to measure the time it takes each person to read five lines of print. You will generally find that the normally slower reader will win.

16.13 How well can you use a rear vision mirror, as in a car? Set up the mirror and ask your partner to act as "driver". Stand at least 10 metres behind the driver. Take a single step in one of four directions — backwards, forwards, right or left. Ask your partner to say which way you moved each time.

16.14 Make a pinhole "camera". Choose two jam tins — one a little smaller than the other so that it will fit inside the larger. Cut the bottom and top out of the smaller tin and cover one end with greaseproof paper to act as a screen. Punch a nail hole in the bottom of the larger tin. Fit the smaller tin into the larger with the screen inside. This shields the screen from outside light. Point the camera at the skyline and look for the image on the screen inside. (Refer to figure 16.1.)

16.15 Place two plane mirrors upright and exactly at right angles with edges touching. Stand a wrist watch in front of the mirrors so that it is facing the junction of the two. What do you notice about the image of the watch?

16.16 Stand two plane mirrors upright, parallel and facing each other. Stand a stick of chalk between the mirrors. How many images can you see?

More questions

16.17 What is the best way to position a reading lamp on your desk so that you get no reflected glare?

16.18 Why is a beam of light outlined on a foggy night?

16.19 How would you estimate the thickness of a plate glass mirror that was mounted so that the edges were invisible? (Hint: place a pencil point on the surface and look at the image.)

16.20 What is a kaleidoscope? Try to obtain one and find out how it works.

Test yourself (chapter 16)

Write the answers to the following in your workbook:

1. An eclipse of the sun occurs when the (a) __________ is between the (b) __________ and the (c) __________.
2. Write labels for (a), (b), (c), (d) on figure 16.11.

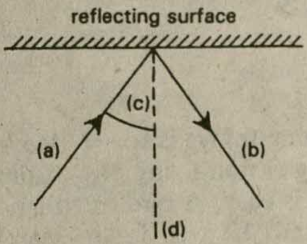


Figure 16.11

3. The image seen in a pinhole camera is a __________ image.
4. A point of light produces shadows with no __________.
5. Images are produced by reflection from __________ surfaces.

In questions 6 to 8, choose the best answer and write its letter in your workbook:

6. Light is scattered most when it strikes a surface that is:
   (a) smooth
   (b) opaque
   (c) rough
   (d) transparent.
7. The image produced by a pinhole camera is:
   (a) inverted and real
   (b) inverted and virtual
   (c) upright and real
   (d) upright and virtual.
8. The image produced by a plane mirror is:
   (a) virtual and laterally reversed
   (b) real and laterally reversed
   (c) virtual and inverted
   (d) real and inverted.

17

Living and non-living things

One simple way of grouping things is to ask whether they are living or non-living. In most cases the answer is easy. A bird flying through the air and the tree in which it nests are obvious examples of living things. The tree, however, might be dead, and this might lead us to consider having a third group — things and materials that are now dead but came from living things.

However, it is not always easy to decide whether something is living, came from a living thing or is non-living. Look at photographs 17.1 and 17.2. One shows lichen on a roof tile and the other an alum crystal growing in a solution. If you were asked whether the lichen is living or non-living, you would probably say "living". And if asked why, you might answer, "because it is growing". Are we therefore entitled to say that the alum crystal is also living, because it too is growing?

In this chapter we look at the subject of living and non-living things in more detail. When you have read the chapter you should be able to decide that the alum crystal is non-living and give reasons for your decision.

Characteristics of living things

What would an object need to do or have before we could say it was living?

Movement. Living things can move. Animals show this ability much more than plants, because they must move in search of food and to escape their enemies. Plants, unlike animals, make their own food from the substances around them. The way they do this is treated in chapter 23. They show only limited movement, as, for example, the turning of a flower towards the sun.

Growth. Young organisms grow until they reach maturity. As growth takes place various changes may occur. Have you watched tadpoles turn into frogs, mosquitoes develop from "wrigglers" or grubs become moths? These sorts of changes are quite remarkable and occur in many growing organisms.

Assimilation. Living things can absorb non-living material and turn it into living tissue in their bodies. For example, people eat such things as bread, cheese and meat, which are digested and changed into flesh, bone and blood. This process of absorption and change is called assimilation. A piece of rock such as sandstone could absorb some water and fertilizer, but it could not change it into new rock.

Response. Living things are usually influenced by their surroundings. Many plants, for example, respond to the presence of a nearby support by twining around it. Animals generally show more

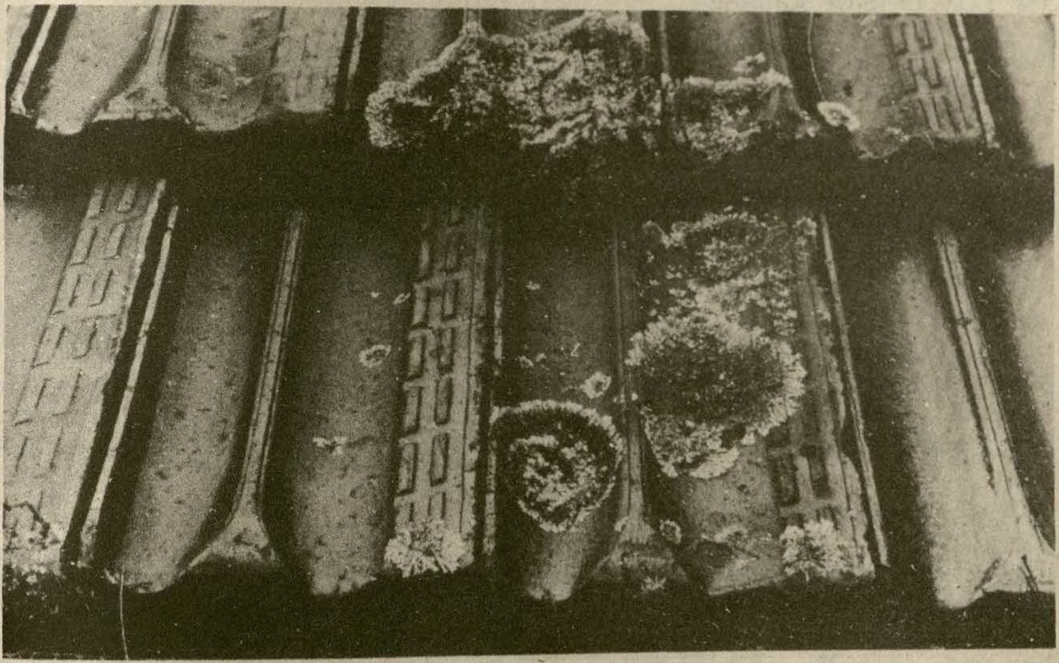


Figure 17.1: Lichen on roof tiles. Where does it come from? Is it a form of corrosion? Is it living or non-living?

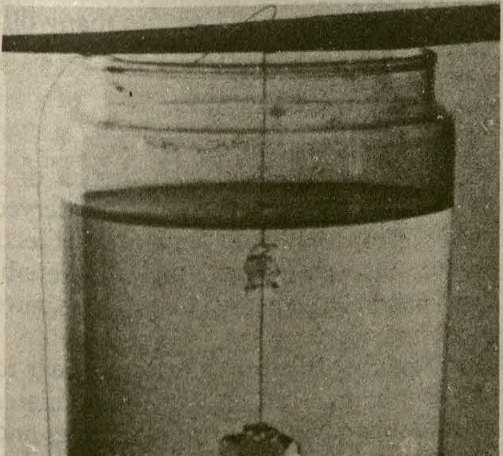


Figure 17.2: An alum crystal growing in a solution of alum. Is it living or non-living?

response to outside stimuli than do plants. How would you, for example, respond to a sudden pin prick, or a sudden loud report?

Reproduction. Living things can make new living things. This process is called reproduction. Many types of plants form seeds, which grow and develop into new plants of the same kind. Most animals produce eggs, which become embryos. The embryos grow and develop into young animals of the same kind.

All of these characteristics of living things are possible only because of the energy an organism derives from the food it absorbs. Non-living things generally show none of these characteristics.

Living or non-living?

Looking at a child playing with a dog or a fly hovering over food, it is easy to appreciate that these are living animals. With some things, however, it is not so easy to decide at once that they are liv-

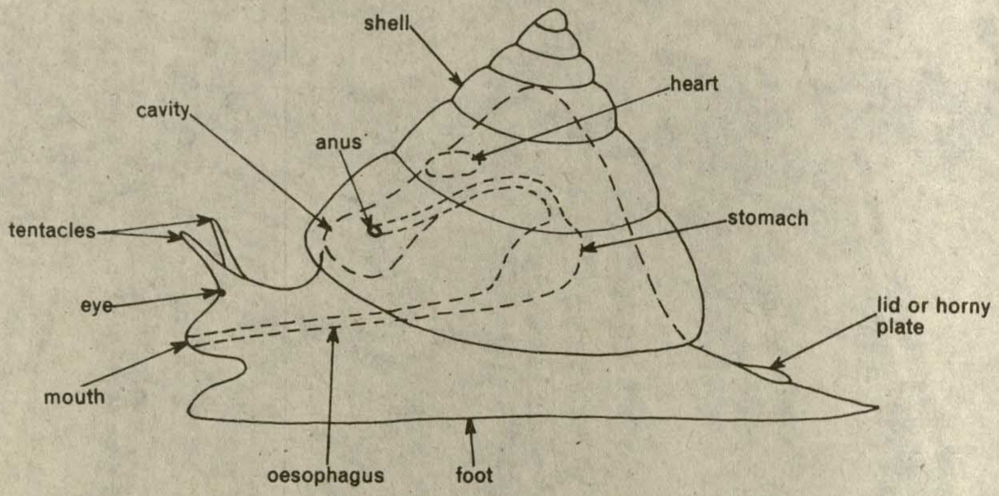


Figure 17.3: Periwinkles are marine snails. They live between tide marks at the water's edge and so spend much of their time in air. They resist drying by retiring into their shells and closing the opening with a horny plate on the foot.

ing. We shall now examine some of these less obvious examples.

Periwinkles

Have you ever been exploring on the rocks by the sea? If you have, you will have seen small objects with hard shell coverings stuck to the rocks. Figure 17.3 is an enlarged drawing of one of these objects. They are called periwinkles.

At first glance you cannot tell whether periwinkles are living or not. If you observe them for some time, however, you may see them moving about slowly, possibly searching for food. The periwinkle is a relative of the garden snail, which eats tender young plants. If you are not satisfied that the periwinkle is a living thing, prise one off the rocks and place it on a sheet of glass. The movement of the soft parts of its body under the shell can then be observed from beneath the glass.

Figure 17.3 shows the body parts of a periwinkle. Periwinkles and snails are called *molluscs*. Molluscs are soft-bodied animals living in shells that they build as they grow. There are many different kinds of molluscs.

Slaters

Have you ever turned over a rock or a brick in the garden and observed underneath numerous dark grey objects about one centimetre long? These objects are slaters, or wood lice. (See figure 17.4.)

When first disturbed slaters appear to be non-living, but the light stimulates them into activity and soon their legs and feelers can be seen moving. The slater likes moist dark places and feeds on dead plant material. It is a relative of the prawn, the crayfish and the lobster, all of which are familiar sea foods. (These animals are called *crustaceans*.)

Seaweed

People who go surfing occasionally find

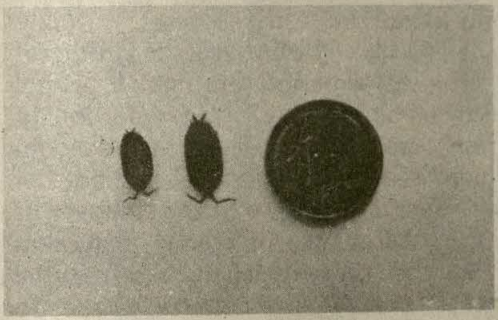


Figure 17.4: Slaters, also called wood lice, are among the few land crustaceans. They are found under logs and stones and feed on decaying vegetation. Photo natural size.

conditions very dangerous owing to an abundance of seaweed. The weed has been washed off the rocks to which it was attached and brought in to the beach by heavy surf.

If some seaweed is removed from the sea it does not show any signs of being a living organism. When observed over a long period while it is attached to the rocks, however, it is seen to grow and to produce new plants. Seaweeds are simple plants called algae. Algae have no stems, leaves or roots like plants in the garden and they usually grow in water. The green scum on ponds is also an alga.

Mould on cheese

If some cheese is left uncovered for several days during warm humid weather, a green mould may form on it. Would you consider this mould to be living or non-living? To answer this question, the mould is observed closely for several days. The threads of the mould are seen spreading out over the cheese as if the mould is a living thing. It is feeding off the cheese.

Scientists have done much research on moulds. One result of this research is the use of the *penicillium* mould to produce the substance penicillin. Moulds are classified as fungi — thread-like organisms that feed off dead plant and animal matter and can reproduce themselves. Mushrooms are another example of fungi. (See figure 17.5.) Fungi make spores, which are released into the air. These spores are so tiny they cannot be seen with the naked eye. Should one settle on suitable food, a new fungus may grow.

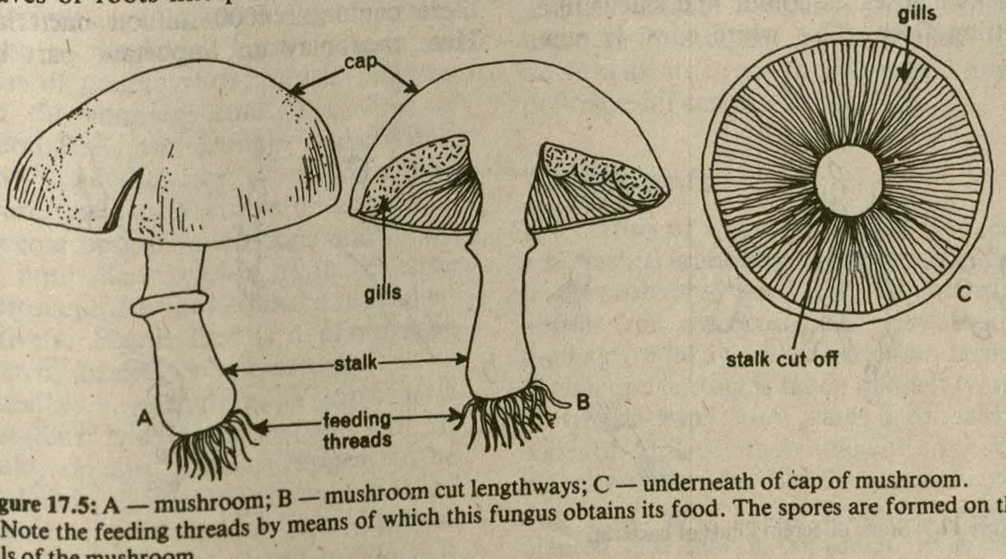


Figure 17.5: A — mushroom; B — mushroom cut lengthways; C — underneath of cap of mushroom. Note the feeding threads by means of which this fungus obtains its food. The spores are formed on the gills of the mushroom.

A growing crystal

In chapter 13 we described how a large crystal of alum may be grown (see also figure 17.2). Because the alum crystal grew, can it be assumed that alum is living material?

Living things assimilate food and in so doing change the food chemically. Living tissue added to a growing organism is therefore different from the food that the organism absorbs. The flesh on our limbs is quite different from the grilled chops and eggs we may eat for breakfast. However, the material added to a growing crystal is the same as the solute in the solution from which the crystal is growing. A growing crystal cannot therefore be considered to be a living thing.

Coral

If you have been to the Great Barrier Reef in Queensland, you will remember the beautiful array of colours displayed by the corals. Is this coral living or non-living?

If a piece of coral is removed from the reef and left exposed to the air for a few weeks it loses its colour and smells like rotting flesh. This white coral is now only a dead skeleton.

If you closely observed the coral reef itself over a period of time, it would seem to be growing by the addition of fresh coral. But we have already concluded that growing crystals are not living. Here, however, we have evidence of life in the change of colour that takes place when the coral is removed from the reef. Actually the colour is due to millions of tiny animals called *polyps*. When they die they leave behind the limestone skeleton that supported them. The reef itself is made of this limestone, which has been secreted by the polyps. (See figure 17.6, facing page 217.)

Bacteria and viruses

Bacteria are very small one-celled organisms about one-millionth of a metre long. They exist in a great variety of shapes that can be seen clearly under a high-powered optical microscope. Figure 17.7 shows some different kinds of bacteria.

Bacteria are everywhere in the biosphere in fantastic numbers. For example, in one gram of manured soil there could be 4000 million bacteria. Here they play an important part in

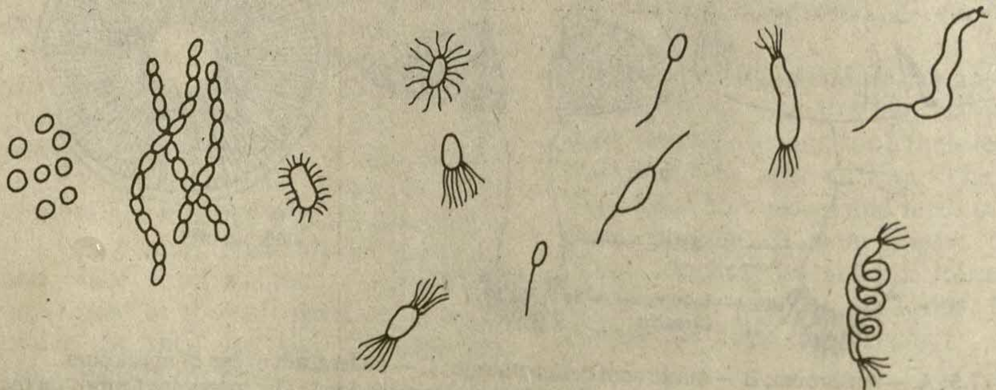


Figure 17.7: Some different kinds of bacteria.

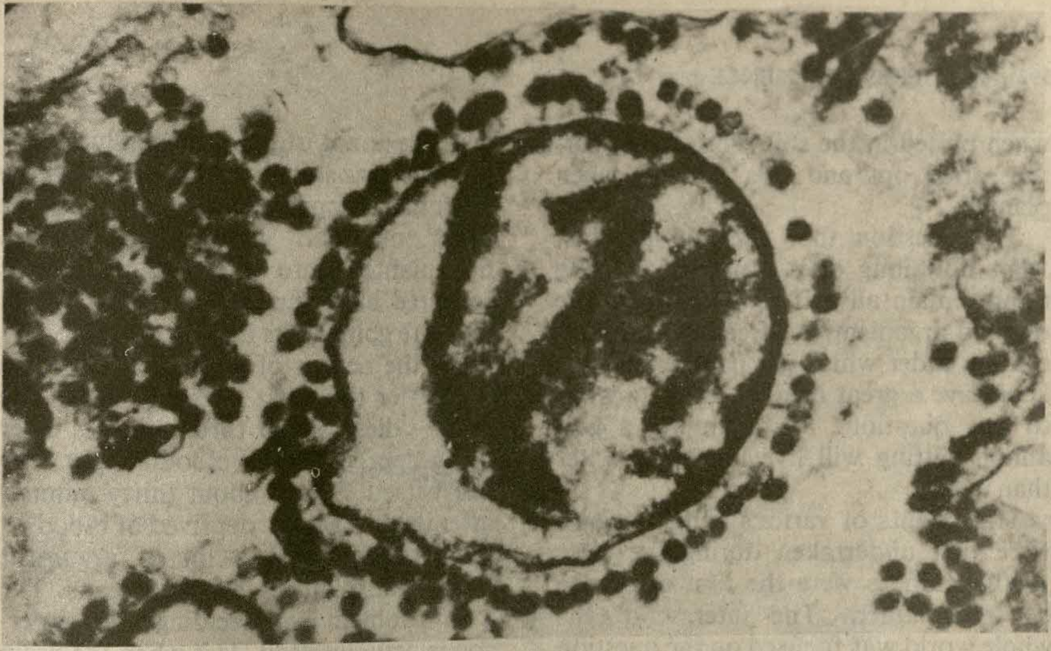


Figure 17.8: A bacterium being attacked by viruses. The viruses are the small dark objects surrounding the

breaking down manure and other material to form salts that are used by plants. Our own bodies contain many bacteria. Some kinds of bacteria are harmful to animals and may cause illness.

Viruses are even smaller than bacteria. Some of the better known viruses are those of poliomyelitis, measles, mumps and the common cold. The virus of poliomyelitis, for example, is about one-fiftieth of the size of a bacterium. Viruses are barely visible under a high-powered optical microscope and it was not until the invention of the electron microscope that they could be studied effectively. Figure 17.8 is a photograph taken by an electron microscope.

Unlike a bacterium, a virus is a crystalline body with no cell wall. It would, on this evidence, appear to be non-living. However, the material of which a virus is made is quite different from the bacterium or cell in which it lives and reproduces — this indicates that it is a living thing.

Viruses eventually kill the cells on which they are "feeding". Each kind of virus tends to attack one kind of cell only. The virus of poliomyelitis, for example, attacks nerve cells. Since muscular movement is controlled by nerve cells, it is easy to understand how poliomyelitis can cause paralysis.

Transplants

If a cutting of a geranium plant is taken and pushed immediately into garden soil it will probably "take". New shoots will appear from the cutting and it will eventually grow into another geranium bush. If a second cutting is taken and left lying in the sun away from water it probably will not "take" when planted. An explanation could be that the original cutting was still living material when planted and that it continued to grow when placed in the soil. The second cutting dried out and was "dead" when planted.

The question that rises to mind is, "For how long does a part of a living thing remain alive if removed from the original organism?" Of course, the conditions under which the part removed is kept have a great bearing on the answer to this question. For example, a geranium cutting will live longer in water than in air.

Transplants of various human organs were first undertaken during the early 1960s. Kidneys were the first organs to be transplanted. The interest of the whole world was focused on the question of transplants at the end of 1967, when the first heart-transplant operation was performed in South Africa. In the years since then, many of these operations have been performed throughout the world. Few were permanently successful and an argument arose as to whether it was right to carry out these operations. Was the donor of the heart really dead if his heart was still alive? It is true that the heart had stopped beating, but it was still living material. After it had been transplanted into the patient it was restarted by electrical shock and it then kept life going in its new owner.

All the organs of an animal die some time after the heart ceases to beat. The brain "dies" some three minutes after being deprived of its blood supply. The heart itself "dies" about thirty minutes after its muscles are deprived of blood.

There has been a lot of argument about transplanting human organs. The main problem is in deciding when a person is actually dead. Is it when the brain has died or when the heart has died? If organs are to be taken for transplanting, the decision on death is made by more than one doctor. The point of death is taken as the time when the cells of the brain are no longer living and cannot be brought to life if blood is recirculated to them.

EXPERIMENT 17.1

Sorting out living and non-living things

Each group will need:

- a large number of different objects and materials such as shells, stones, a pot plant, bread, wood, a nail, glass, crystal of bluestone, a feather, cotton cloth (labelled as cotton), small animals (ants, grubs, moths and so on), some hair, water
- hand lens

What to do

- Examine each item, using a hand lens if necessary.
- Copy the following table and write the name of each item in the appropriate column:

Living	Non-living	
	Dead, or came from living things	Never alive

EXPERIMENT 17.2

Studying movement and response to stimuli in snails

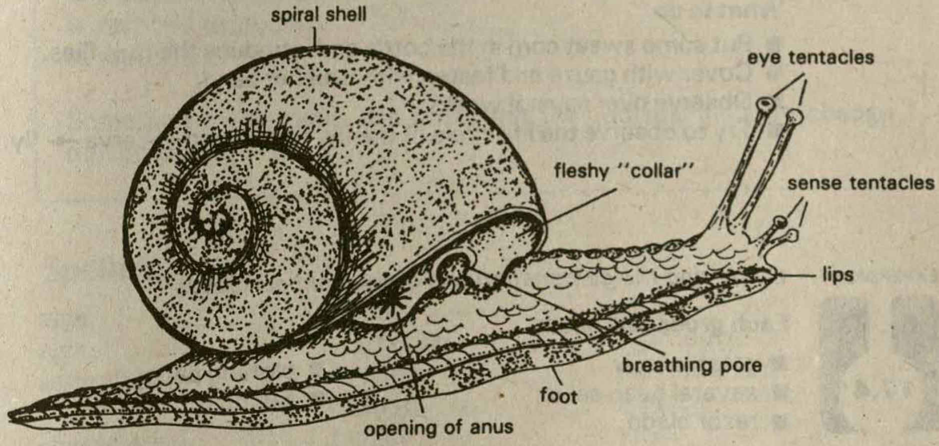


Figure 17.9: External features of the common garden snail.

Each group will need:

- garden snail
- glass rod
- methylated spirits
- hand lens
- sheet of glass

What to do

- Place the snail on the bench and wait for it to move.
- When it moves, dip a glass rod in methylated spirits and hold it about a centimetre in front of the animal.
- Note the response. Notice particularly the reaction of the lower tentacles.
- Repeat the experiment, using a clean glass rod. Does the snail avoid contact with the rod?
- Place the snail on a clean sheet of glass and watch from below. Note the waves of muscular movement from back to front. It is the movement of these muscles that pushes the snail forward.
- Use the hand lens to look for the anus. It cannot be seen unless the animal is actually excreting.
- Hold a small snail against a bright light. You will probably see the beating of the heart.

EXPERIMENT 17.3

Studying the reproduction of the fruit fly

Each group will need:

- small milk bottle
- piece of gauze cloth
- rubber band
- some creamed sweet corn
- some fruit flies

What to do

- Put some sweet corn in the bottle and introduce the fruit flies.
- Cover with gauze and fasten with a rubber band.
- Observe over several weeks.
- Try to observe the life cycle of the fly, that is, egg → larva → fly.

EXPERIMENT 17.4

Observing the germination and growth of bean seeds

Each group will need:

- glass jam jar
- several bean seeds
- razor blade
- blotting paper
- sawdust

What to do

- Split one bean seed through the middle to expose the embryo plant.
- Fold the blotting paper into a tube the length of the bottle and fit it inside the bottle.
- Push the remainder of the bean seeds between the blotting paper and the glass. Vary the positions of the seeds, so that the white scar of one seed is facing upwards, of another sideways, of another downwards, and so on.
- Fill the bottle with sawdust and add enough water to make the contents of the bottle damp.
- Add more water occasionally and watch the bean seeds over several weeks.
- When the beans have shoots about 3 cm long, turn the jar carefully upside down and leave it for a number of days.

Questions

17.1 What appeared first – the shoot of the young plant or the root?
17.2 Did the position of the seed make any difference to the direction of growth?
17.3 What happened when the jar was inverted and left for a few days?

Living and non-living things

Living things can:

- move
- grow and undergo changes
- assimilate food
- respond to stimuli
- reproduce.

Some non-living things can grow, but they do not undergo change during growth.

Spelling list

alga
algae
assimilate
bacteria
characteristic
coral
crustacean
crystal
crystallize
develop
embryo
fungus
mollusc
mould
reproduce
reproduction
tentacle
virus
viruses

Things to do

17.4 Obtain some silkworm eggs and lettuce leaves. Observe the cycle: egg → caterpillar → pupa → moth.

17.5 Make a wormery from a small aquarium. Fill it with rich garden soil. Add some worms and keep the soil damp but not wet. Try to discover the life cycle of the garden worm.

17.6 Keep a pair of mice (a male and a female) in a mouse cage for 8 or 9 weeks. Supply sawdust and shredded paper for nesting. Clean the cage regularly, but disturb the mice as little as possible.

Find out when mice eat, sleep and exercise. Identify the male and the female. What time passes before a litter is born? Find out what a mouse does in strange surroundings. Would it rather be in a cardboard box or in an open space?

17.7 Grow some mould on bread. Examine it with a hand lens. Look for the threads by which the fungus feeds. Suppose someone said that mould "is only dirt within the bread". Could you argue that mould is a living thing?

17.8 Grow some bacteria on agar jelly in a petri dish. Find out whether there are any bacteria in your saliva, or in the air.

More questions

17.9 Name five characteristics of living things. Which of these are more evident in animals than in plants?

17.10 What are the arguments for and against transplanting a heart from a dead person to a living person? Can a dead heart be transplanted?

17.11 Are seeds living or non-living? Give reasons for your choice. Why is there a date stamp on a packet of seeds?

17.12 How many stomachs does a cow have? Do bacteria play any part in the digestion of food in a cow's body?

17.13 In this chapter we have listed some of the viruses that can infect the human body. Are there any bacteria that cause disease?

Test yourself (chapter 17)

Write the answers to the following in your workbook:

1. Answer each of parts (a) to (e) by choosing one word from the column on the right.

(a) The process by which living things absorb dead material and change it into living tissue is called __________. (b) Living things will respond to __________. (c) Living things can __________, that is, produce more living things of the same kind. (d) Both crystals and living things can __________. (e) You may be wrong if you say a thing is dead because it will not __________.	response stimuli assimilation digestion grow reproduce develop move die

Choose the best answer to each of the following questions and write its letter in your workbook.

2. Two of the following groups contain only substances that come from living things. Which are they?
   - (a) copper, orange juice, wood
   - (b) sugar, cotton, linen
   - (c) rope, table salt, butter
   - (d) wool, coal, pepper.
3. We know common table salt is non-living because:
   - (a) it is crystalline
   - (b) it comes from sea water
   - (c) its crystals grow only in salt solution
   - (d) its crystals do not cause infection.

18

Adaptations in animals

Humans share the world with many other animals. Humans can live in most parts of the world because they have the knowledge and skill to make things comfortable for themselves. The other animals, however, can survive only in those places to which they are suited. Fish, for example, are adapted to live in water. They breathe the oxygen dissolved in the water through special organs called gills.

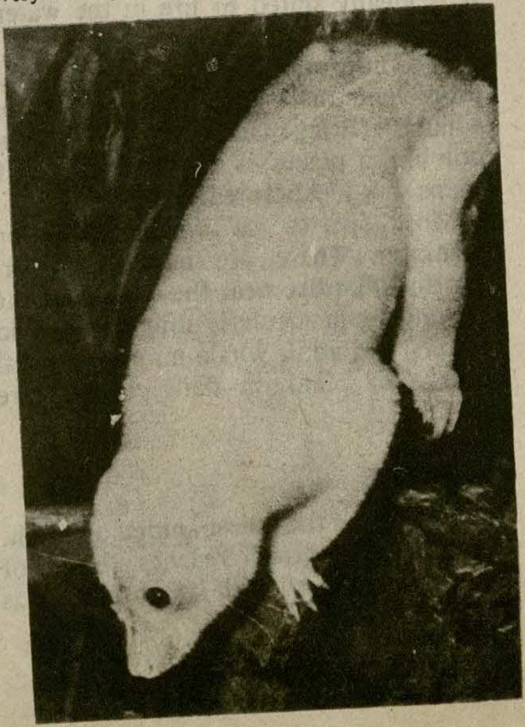
The simplest sorts of animals have no backbones and are called *invertebrates*. Periwinkles and snails, which were mentioned in the previous chapter, are invertebrates. The more complex animals do have backbones — these are the *vertebrates*. Among the vertebrates are mammals, reptiles, amphibians, birds and fishes. The mammals are of particular interest to us for we belong to this group. In this chapter we will study some different kinds of mammals and show how their bodies fit them for survival in the conditions under which they live.

Mammals

Mammals are so named because the female suckles her young from mammary glands, which secrete milk. Mammals generally have a covering of hair or fur and a constant body temperature. In a reptile, such as a snake, the body temperature varies. It is high during warm weather and low during cold weather.

Mammals are found in all parts of the biosphere. The biosphere is that zone on the earth's surface — sea, land and air — that supports life. The ability of the mammals to survive in their various habitats is due to the way their bodies are constructed.

Figure 18.1: A cuscus, photographed at night. The cuscus is a marsupial native to Papua New Guinea and northern Australia. Its very large eyes are an adaptation enabling it to see when there is very little light.



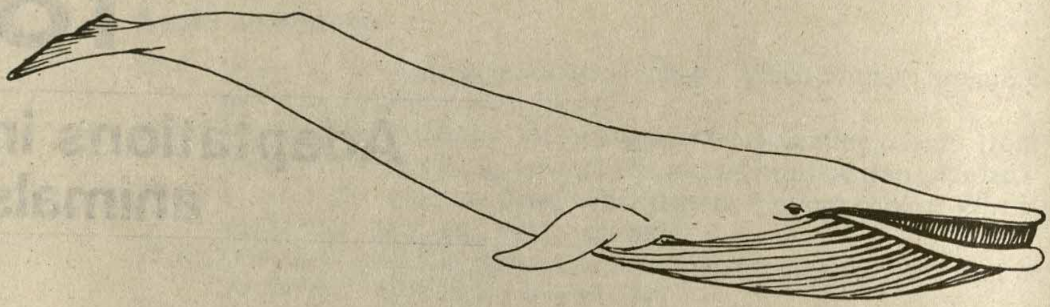


Figure 18.2: The blue whale grows to a length of over 30 metres. Note the wall of bristly plates attached to the roof of the mouth. These plates are called baleen and act as strainers to catch food when the whale is feeding. The blue whale feeds on krill, tiny organisms that occur in great numbers in Antarctic waters. The whale gulps huge quantities of sea water, squirts the water out through the baleen and swallows the minute animals left behind. A mature whale can eat as much as 8 tonnes of krill a day.

Whales

The whale is the largest animal on earth. A weight of over 100 tonnes is not unusual for a fully grown specimen. A land mammal of this weight would be a most awkward creature and would be most unlikely to survive. Yet the whale moves with great speed through the water. It is beautifully streamlined and possesses tremendous strength in its tail. It is ideally suited to life in the water, which supports its great weight.

Breathing air through lungs like all other mammals does not affect the whale's efficiency in the water. Like the dolphin, it possesses an air spout, which snaps shut just before it submerges.

Most species of whales feed on plankton. These are microscopic organisms that live near the surface of the sea and are particularly abundant in cold waters. An adult whale may eat several tonnes of plankton daily. (See figure 18.2.)

Giraffes

The giraffe is the tallest animal on earth. A fully grown giraffe reaches a height of about six metres. With its long neck it is

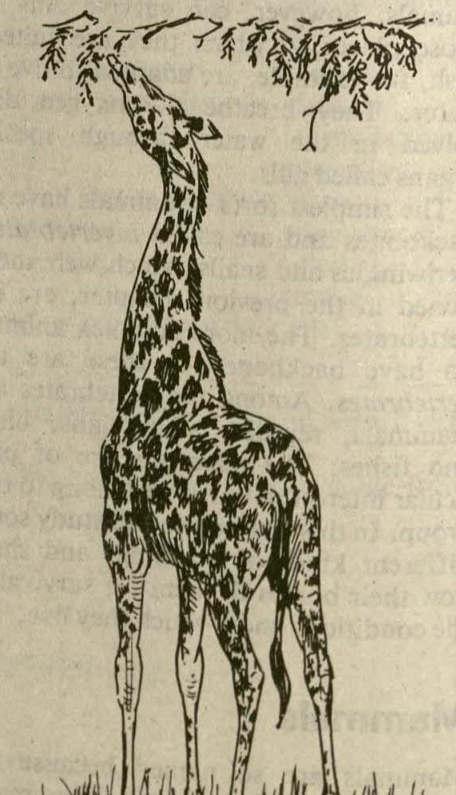


Figure 18.3(a): The long neck and long legs of the giraffe adapt the animal to feeding on high bushes and trees.

well adapted to feed off high bushes and trees. (See figure 18.3a.) The giraffe is assisted also by a long, flexible tongue that can be extended and wrapped round tender leaves and shoots.

The giraffe could not survive in treeless country. Its head can reach the ground only after a laborious spreading of the legs. (See figure 18.3b.) In this awkward position it would feed very slowly and would be more open to attack from the lion, its main predator. The giraffe's blotches make it almost invisible in the thin cover where it lives. This is especially so at dusk, when the lion is most likely to attack.

Bats

The bat is a mammal that is adapted for flight. It possesses a wing membrane that extends from the arm to the leg and tail, as shown in figure 18.4.

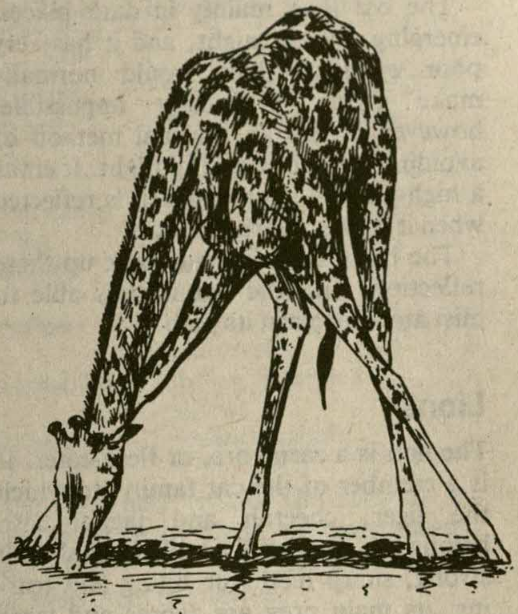


Figure 18.3(b): A drinking giraffe. While in this awkward position the giraffe is vulnerable to attack by its principal predator, the African lion.

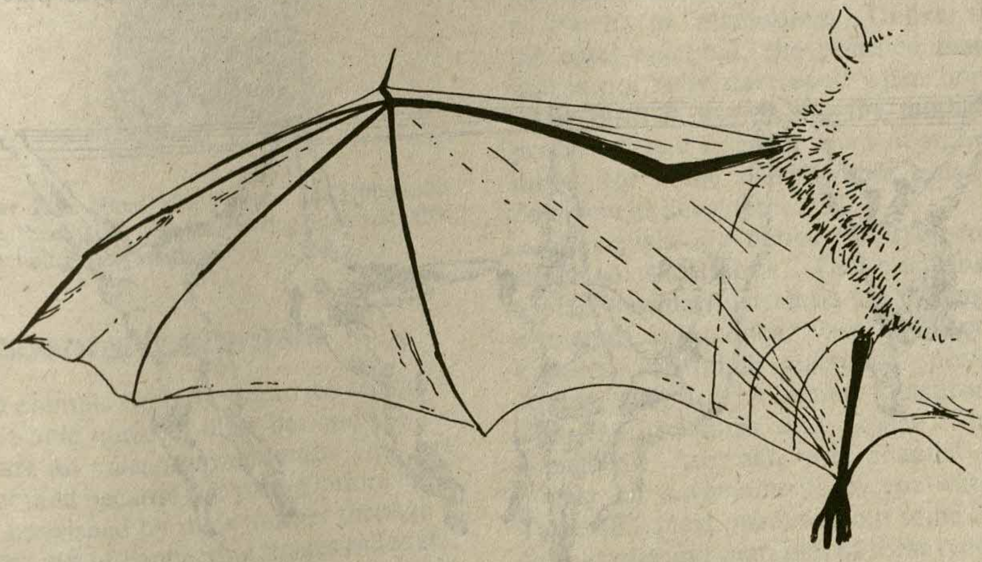


Figure 18.4: The structure of a bat's wing. A membrane stretches from fore limbs to hind limbs and tail. Note the greatly elongated fingers supporting the membrane.

The bat lives mainly in dark places, emerging only at night, and it has very poor eyesight. This would normally make flying practically impossible; however, it has an unusual method of avoiding collisions during flight. It emits a high-pitched sound, which is reflected when it strikes nearby objects.

The bat's sensitive ears pick up these reflections and the bat is thus able to miss any objects in its path.

Lions

The lion is a carnivore, or flesh-eater. It is a member of the cat family, to which the tiger, cheetah and jaguar also belong. A powerfully built animal with strong, sharp teeth for biting and tearing, its main prey are zebras and large antelopes. The lion attacks its prey only when forced to do so by hunger; it uses stealth combined with a quick burst of speed to run down its victim.

The lion inhabits open grassland in Africa. Its reputation as the king of the jungle is not very apt; it would probably starve in the jungle for it requires plenty of space to run down its fleet-footed prey.

Gibbons

The gibbon is an ape standing only about one metre tall and weighing no more than twelve kilograms. It is the most arboreal of the apes. It moves by swinging itself from branch to branch, clutching briefly with alternate hands before again hurling itself forward. (See figure 18.5.)

The gibbon is wonderfully adapted for this manner of movement. It possesses long forelimbs; its arm span easily exceeds the total length of its body and legs. In addition its hands have extraordinarily long, strong fingers that can be flexed into loops for hanging and swinging. (See figure 18.6.) Finally, like the other apes, the gibbon has eyes placed

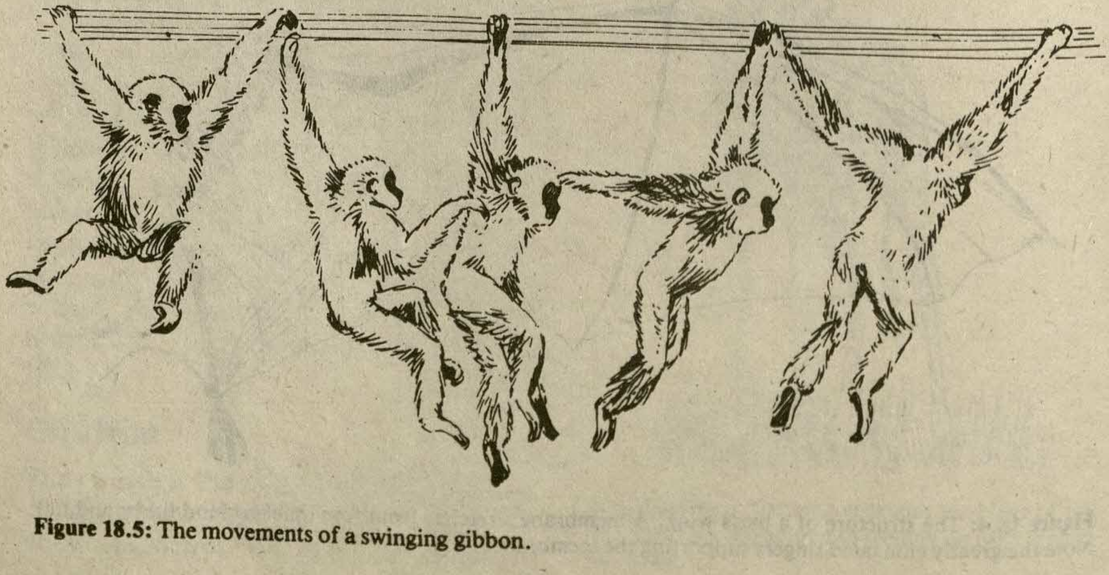


Figure 18.5: The movements of a swinging gibbon.

well forward on the head. Both eyes can therefore see the one object at the same time. This makes the gibbon a good judge of distance.

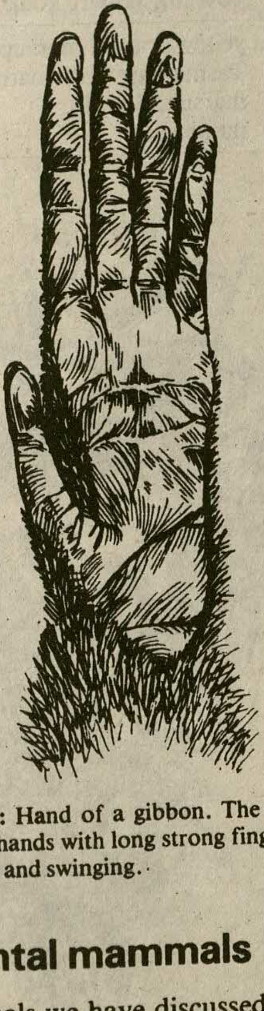


Figure 18.6: Hand of a gibbon. The gibbon has specialized hands with long strong fingers suitable for hanging and swinging.

Placental mammals

The animals we have discussed so far — the whale, giraffe, lion, bat and gibbon — are all *placental mammals*. They are so named because the young before birth are nourished by their mother through a collection of connecting tissues called the *placenta*. Table 18.1 sets out some of the types of placental mammals and gives examples of these types.

Table 18.1: Placental mammals

Type	Examples
swimming	whales, dolphins, seals
hoofed	giraffes, deer, sheep, cattle, tapirs, zebras, horses
flesh-eating	the cats, dogs, bears
flying	bats, flying foxes
thinking	lemurs, monkeys, apes, humans
toothless	sloths, armadillos, giant anteaters
insect-eating	moles, hedgehogs, shrews
gnawing	rodents, rabbits

On your next visit to the zoo, try to identify some of these animals. Study them closely and note the adaptations that help them to survive.

Pouched mammals (marsupials)

Pouched mammals are those possessing a pouch, or marsupium. Unlike the placental mammal, the pouched mammal is not fully developed when born. After birth it crawls into the mother's pouch where it fixes on to a teat and remains for some considerable time to complete its development.

Marsupials are almost entirely confined to Australasia. The only marsupials outside Australasia are the small opossums of America. There are over a hundred Australian marsupial species. Among these are the familiar kangaroos, wallabies, possums and koalas. Marsupials in Australia are adapted to almost all environments except water. Table 18.2 (next page) sets out some different types and examples of these types.

We shall briefly examine some of the adaptations of two of the tree dwellers.

Table 18.2: Marsupials

Type		Examples
Plant eaters	grazers	kangaroo, wallaby
	underbrush dwellers	rat kangaroo
	diggers	wombat
	tree dwellers	possum, glider, koala
Carnivores	"mice"	yellow-footed marsupial mouse
	"cats", "devils", "wolves"	Tasmanian wolf, native cat
	moles	marsupial mole
	anteaters	numbat

Koalas

The koala is a woolly marsupial, snub-nosed and round-eared. When fully grown it weighs about thirteen kilograms and is about three-quarters of a metre in length. (See figure 18.7.)

The koala has a highly specialized diet of *Eucalyptus* leaves, which are poisonous to most other animals. In fact the koala can eat only about six of the some 400 species of *Eucalyptus* that are available. It has an extension to its intestine, like an overgrown appendix, which scientists think helps it to digest its food. Furthermore this intestine contains a large number of bacteria that assist the koala in the digestion of the leaves. Without the bacteria the koala would die, and without the food supplied by the koala the bacteria could not survive.

The koala comes to ground only to move from tree to tree. It has no need to come down to drink for it can get all the water it needs from the dew on the leaves it eats. It is well adapted for climbing. The hand is divided into two sections, one with three fingers and the other with two, and thus it is able to grasp firmly. In addition it possesses sharp claws with which it can get a good grip.

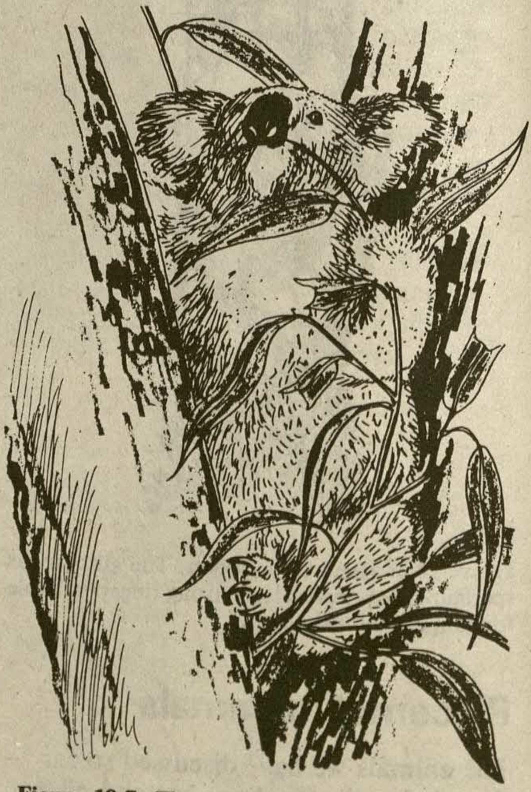


Figure 18.7: The koala eats only one food, the leaves of certain *Eucalyptus* trees, and its whole way of life is related to this diet.

Possums

Possums are tree-dwelling, furry creatures with big eyes and long tails. They have the second and third digits of their hind feet bound together by skin, making a strong double toe. This toe and a big toe that works against it make the possums good tree climbers. The grasping tail is bare of hair on the under surface near the tip to provide a firm grip when climbing.

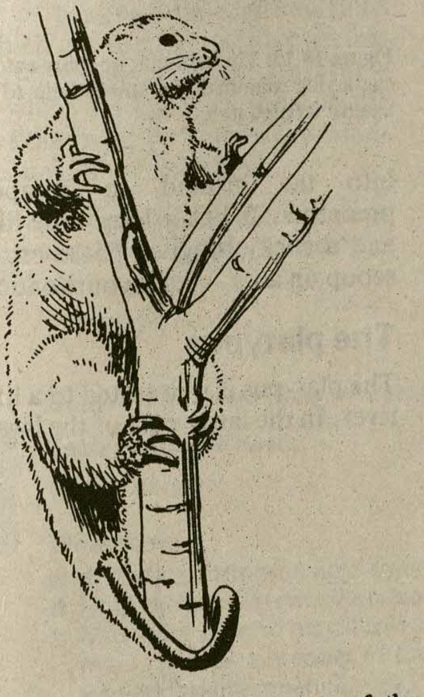


Figure 18.8: The cuscus is the largest of the possums (see also figure 18.1). Slow and drowsy by day, it is easily killed by native hunters in Papua New Guinea.

Possums vary in size. The largest is the 7 kilogram cuscus. (See figures 18.1 and 18.8.) The most common medium-sized possums are the brush-tailed and the ring-tailed varieties. The smallest possum is the pygmy possum, no more than twenty centimetres long.

Certain species of possums have membranes of skin running from the wrist or elbow to the ankle. When the limbs are extended the animal appears almost square. In this position it leaps from tree to tree, gliding for long distances. (See figure 18.9.) Gliding helps the animal to forage extensively through broken forest without having to go to ground where predators may be waiting.

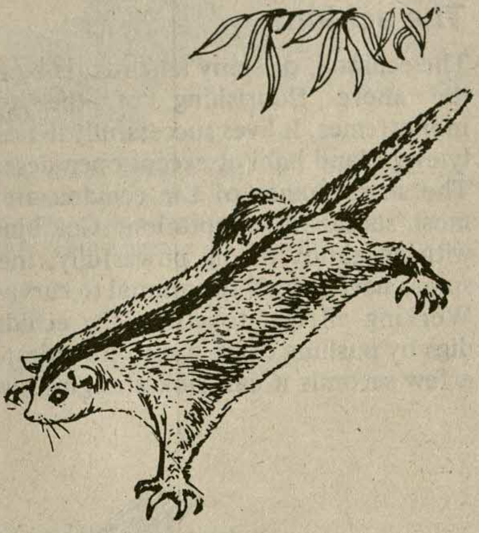


Figure 18.9: The greater glider is capable of gliding almost a hundred metres.

Possums are nocturnal animals. Their large eyes admit a lot of light and enable the animal to see well at night. The Taronga Park Zoo in Sydney has an experimental nocturnal house illuminated during the day by red light. Here visitors can observe the night-time activities of such common marsupials as the brush-tailed and ring-tailed possums and the greater glider. At night the animals are given daytime conditions by the use of white electric light.

Monotremes (egg-laying mammals)

Monotremes are the most primitive of mammals. Although the female monotreme suckles her young, she does not give birth as other mammals do, but lays eggs like the reptiles. There are only two living monotremes — the platypus and the echidna. Both of these are natives of Australia.

The echidna

The echidna, or spiny anteater, is by far the more flourishing of the two monotremes. It lives successfully in nearly every land habitat except open desert. The sharp spines of the echidna are a most successful adaptation. Combined with an ability to dig powerfully, these spines have helped the animal to survive. Working all feet together, the echidna digs by pushing earth out to the sides; in a few seconds it can sink straight down into the ground to escape from predators. It has a long tube-like snout and a sticky tongue. These enable it to scoop up ants — its favourite food.

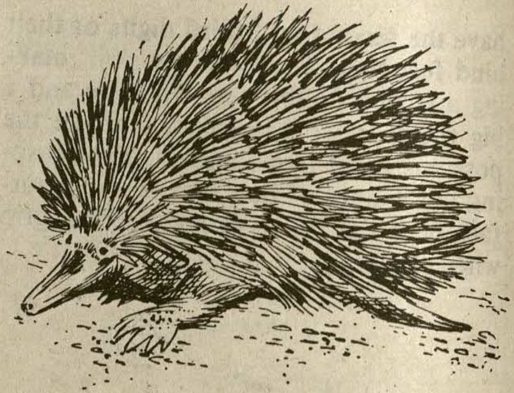


Figure 18.10: The echidna, or spiny anteater, is an egg-laying mammal. Its spines help to protect it against its predators.

The platypus

The platypus is well suited to a life by the river. In the latter part of the last century

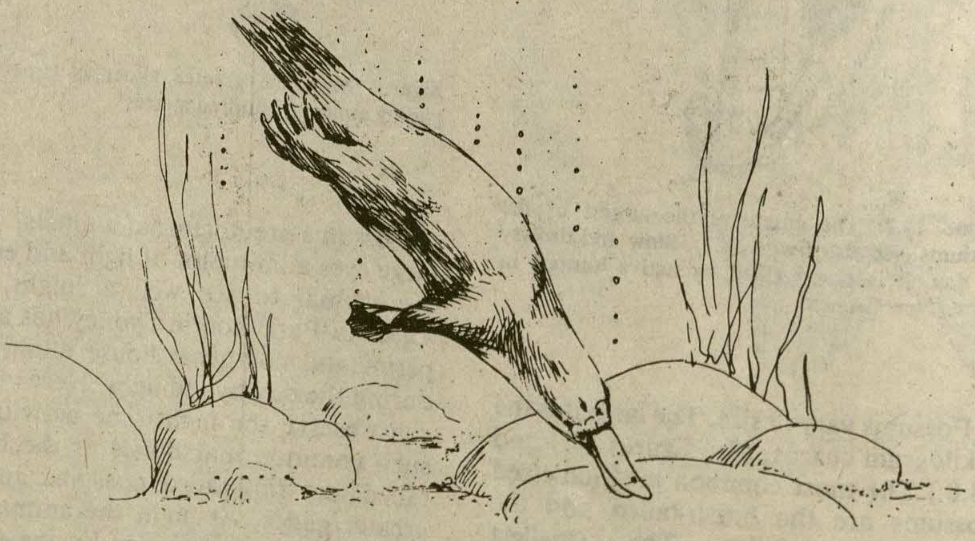


Figure 18.11: Eyes and ears closed by a fold of skin, the platypus dives for food. It uses only its webbed forefeet for swimming.

it was widely trapped for its soft fur. It is now strictly protected.

The platypus is a unique animal. Its limbs are joined to its body in a reptile-like way, and it has a flat muscular tail like a beaver's, which keeps it steady when it swims. The forefeet have a great deal of webbing that can be extended for swimming or tucked under to free the claws for digging. (See figure 18.12.) The hind feet of the male have poison-filled spurs, which are used as defence against predators. The platypus has a sensitive bill with which it locates its food on the bottom of the river. Its burrow is a winding tunnel dug in the river bank.

Figures 18.13 and 18.14 (facing page 216) show another example of adaptation in animals.

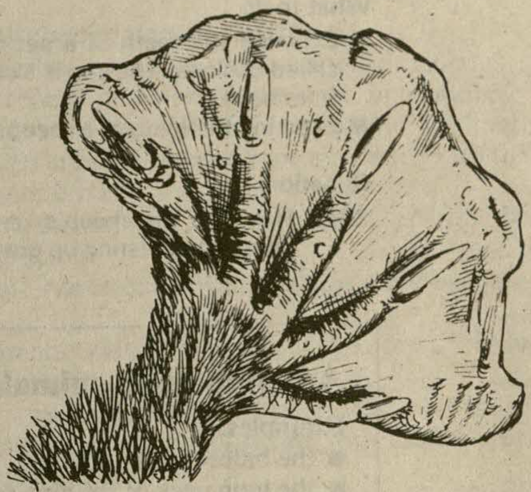


Figure 18.12: The forefoot of a platypus. The webbing can be tucked under to free the claws. This remarkable adaptation enables the foot to be used for both digging and swimming.

EXPERIMENT

18.1

Showing that two eyes are better than one for judging distances

Each group will need:

- two pencils

What to do

- Ask your partner to hold a pencil horizontally in front of you.
- Hold the second pencil horizontally in your hand and close one eye.
- Move the second pencil towards the first with the idea of making the ends meet. Repeat a number of times, each time varying the distance between you and the first pencil.
- Repeat the experiment with both eyes open.

Questions

18.1 Were you more successful in judging distances using two eyes instead of one?

18.2 Which animal is more adapted to jumping over a hurdle — a cheetah or a horse? Why?

EXPERIMENT

18.2

Comparing the mouth of a dog with the mouth of a sheep

Each group will need:

- sheep's head from the butcher

What to do

- Examine the teeth of a pet dog. In particular, notice the fang-like teeth called canines. The dog is a carnivore. How do its teeth help it to tear meat from bones?
- Examine the teeth of a sheep. The sheep is a herbivore.

Question

18.3 How are the sheep's teeth different from the dog's? How are they adapted to tearing up grass and grinding it to a pulp?

Adaptations in animals

Examples:

- the baleen of the whale
- the long neck of the giraffe
- the strong teeth of the lion
- the wings of the bat
- the long forelimbs of the gibbon
- the special digestive system of the koala
- the big eyes of the possums
- the sharp spines of the echidna
- the special webbing on the forefoot of the platypus.

Each of these adaptations helps the animal to survive in its environment.

Spelling list

adaptation
adapted
amphibian
carnivore
echidna
environment
eucalypt
giraffe
herbivore
invertebrate
koala
mammal
marsupial
monotreme
placental
platypus
predator
vertebrate

Things to do

18.4 Visit a zoo; concentrate on looking at the mammals. Often the zoo will supply a brochure listing those features of each mammal that enable it to survive in its natural habitat.

18.5 You may have access to caged mice or guinea pigs. Study these animals. What kind of food do they eat? What kind of teeth do they have? Do they have whiskers? Do they make nests?

More questions

18.6 Name two mammals with good protective colouring.

18.7 List some carnivorous, herbivorous and omnivorous mammals.

18.8 What characteristics do reptiles and monotremes have in common?

18.9 Compare the foot of the antelope with the foot of the elephant. What would happen to the animal if an elephant were born with the feet of an antelope and vice versa?

18.10 How does the webbing on the forefoot of a platypus differ from the webbing on the foot of a duck?

18.11 What is binocular vision? Name one advantage and one disadvantage of binocular vision.

18.12 Name the mammal commonly called "the ship of the desert". How is this animal fitted to survive in the desert?

18.13 The platypus feeds on small animals that live on the bottom of streams. When under water, the platypus swims with closed eyes. How then does it find these animals?

18.14 Draw up and complete a table comparing the domestic cat and the domestic dog. What structures enable you to say both animals are carnivorous? How are they different?

18.15 Would a giraffe die of hunger in the arctic tundra? Explain.

18.16 Many desert animals make burrows in which they rest during daylight. They feed at night. This behaviour helps them in a number of ways. How?

18.17 Humans are the most adaptable of all animals. List some unpleasant or dangerous environments to which humans have adapted.

18.18 Choose a mammal you are particularly interested in. Refer to books to find out more about it — its appearance, its habitat, its food, particular adaptations for its habitat, the effects it has on plant life and other animals.

Test yourself (chapter 18)

Choose the best answer for each question and write its letter in your workbook.

1. Humans are able to adapt to a variety of environments because:
   (a) they have binocular vision
   (b) they are omnivorous
   (c) they can think
   (d) they are mammals.
2. The embryos of placental mammals are carried in their mothers' bodies until birth. While in the body of the mother, the young obtains from the mother:
   (a) food only
   (b) protection only
   (c) food and protection
   (d) food, protection and oxygen.

3. A whale is successful because:
   (a) it can survive in cold waters rich in plankton
   (b) it eats small marine animals
   (c) it is a mammal
   (d) it is large.
4. Which one of the following groups of mammals contains only carnivores?
   (a) cat, dog, sheep
   (b) cat, fox, rabbit
   (c) dog, cat, fox
   (d) fox, rabbit, possum.
5. Which one of the following groups contains only animals adapted to life in trees?
   (a) koala, echidna, monkey
   (b) koala, cat, possum
   (c) cat, monkey, echidna
   (d) possum, wombat, koala.

19

Adaptations in plants

Animals, including humans, eat plants for food or eat other animals that use plants for food. Plants are therefore necessary for the existence of animal life.

Like animals, plants survive only in those places to which they are suited. In this chapter we will study the manner in which plants are fitted for survival in the places where they grow.

Desert plants

In the desert the main problem for plants is the shortage of water. Some plants overcome this problem by storing water in their different parts. Because these plants are full of juice they are called *succulents*. The best-known succulents are the cacti, which range in height from about a centimetre to over 20 metres. (See figure 19.1.)

Thirsty animals are discouraged from trying to get juice from the giant cactus by the spines that grow on its surface. (See figure 19.2.) The surface is also grooved, as shown in figure 19.2. When the plant is taking up water the fleshy stem is able to expand quickly, enabling it to absorb hundreds of litres. The stem contracts again as the plant uses the water. The roots of the cactus are widespread and shallow, which allows them to soak up water quickly after a downpour of rain.

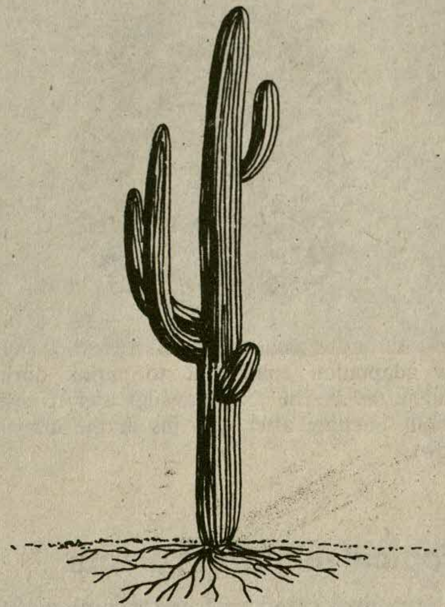


Figure 19.1: The giant cactus grows in deserts in America. In years past, desert Indians mashed up the cactus for liquid in time of drought.

The largest group of desert plants are the flowering annuals. Their seeds can survive in the ground for years and are specially adapted so that they germinate only after about 2 or 3 centimetres of rain. If the seeds germinated after a light shower there would be insufficient water for the plants to grow to maturity and produce seeds for the future. (See figure 19.3, facing page 217.)

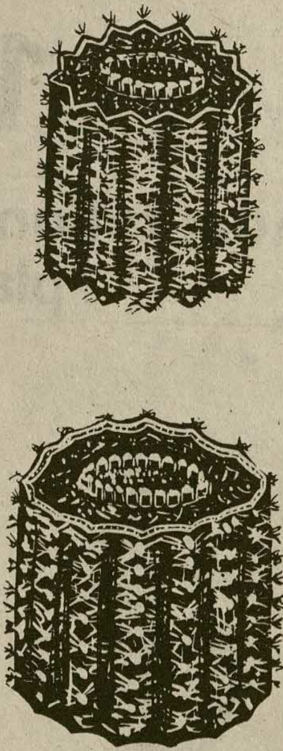


Figure 19.2: The giant cactus has a grooved stem. This adaptation enables it to shrink during drought (as in the top drawing) and to swell without bursting after rain (as in the drawing below).

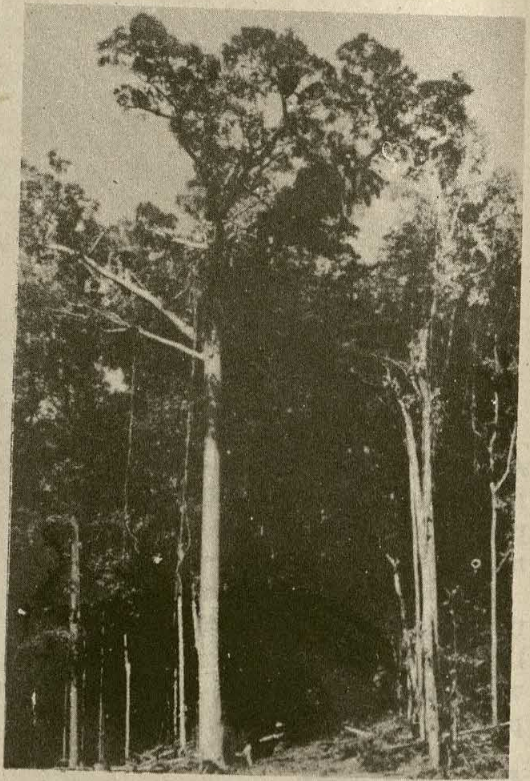


Figure 19.4: Lianas looping a forest tree as they climb towards the light. (Photo courtesy Queensland Department of Forestry)

Tropical rainforest plants

In a tropical rainforest water is plentiful. Many tall trees grow and these form a canopy of leaves that blocks out light from the forest floor. Since plants cannot make their food unless sunlight falls on their leaves, the main problem of forest plants is to grow up through the canopy to the sunlight.

The *lianas* are plants with woody stems. They twine their way up to the light using the forest trees as support. (See figure 19.4.) Once they pierce the forest canopy they bear leaves and flowers.

Other plants survive by growing in the branches near the tops of the trees where they are near the sunlight. These are the *epiphytes*. They form their own soil by trapping dead leaves in the branches where they grow. Some epiphytes store water in specially adapted thick leaves, while others obtain it through roots that dangle in streams as much as 20 metres below.

The water dwellers

Water lilies have their leaves resting on the surface of the water. Their flowers stand well above the leaves. The main problem for these plants is to find and conserve air supplies. Figure 19.5 shows how a water lily gets air to its roots through large channels in the stems.

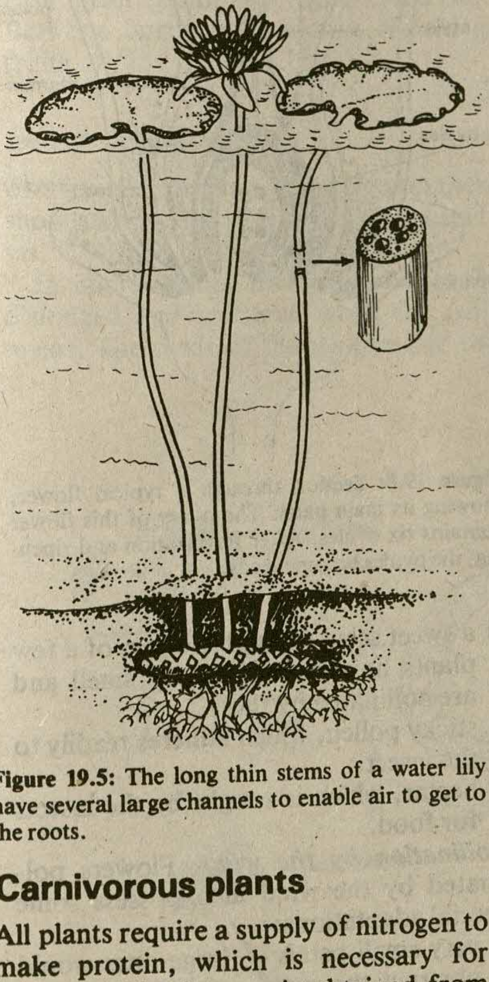


Figure 19.5: The long thin stems of a water lily have several large channels to enable air to get to the roots.

Carnivorous plants

All plants require a supply of nitrogen to make protein, which is necessary for growth. This nitrogen is obtained from salts in the soil. Bogs, however, have a poor supply of these salts. Plants that grow in bogs have special adaptations to overcome this shortage. They obtain most of their protein from the bodies of insects, which they trap with special devices.

Figure 19.6 is a photograph of a pitcher plant. The lips of the pitchers are coated with nectar, which entices insects to enter. Once inside the pitcher, the insect, trapped by stiff hairs and slippery walls, is devoured by the plant.

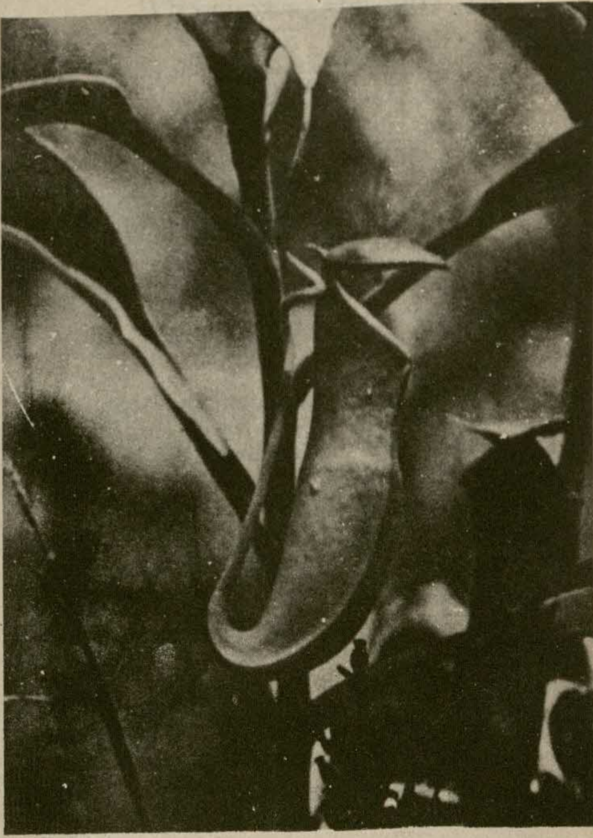


Figure 19.6: The pitcher plant has nectar around the rims of the flowers, which entices insects to enter them. (Photo courtesy W. T. Jones, CSIRO)

Figure 19.7 is a diagram of the sundew plant. This plant has spoon-shaped leaves with sticky tentacles. Insects are caught by the sticky material as they alight on the leaves.

Up to this point we have been looking at plants in different habitats, and the adaptations they have made to survive. For the remainder of the chapter we will look at things all flowering plants have in common, and the ways they can be adapted to suit different conditions.

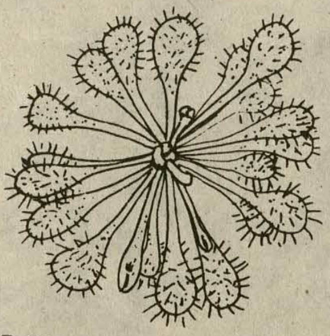


Figure 19.7: The sundew, an insectivorous plant, has sticky tentacles on its leaves. The sticky fluid on the tentacles traps any insects that land on it.

The flowers of plants

The plants discussed in this chapter all bear flowers. These contain the parts that produce seeds. The seeds are enclosed inside a fruit, which protects them. Figure 19.8 is a diagram of a section of a flower, showing its reproductive parts.

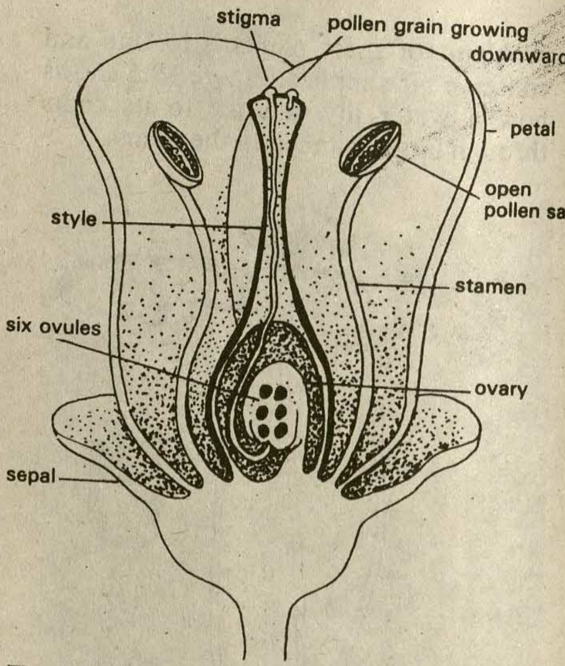


Figure 19.8: Section through a typical flower, showing its main parts. The ovary of this flower contains six ovules. After fertilization and ripening, the ovules become seeds.

Pollination

Pollination is the transfer of pollen grains from the pollen sacs to the stigma. Unless this happens, no seeds will form. Pollination can occur within a single flower or from one flower to another. The pollen grain grows as a long thread down the style into the ovary, where it penetrates an ovule. (See figure 19.8.) The ovule grows into a seed as the flower withers and dies.

Plants may be pollinated either by animals or the wind.

Pollination by animals. The animals responsible for the transfer of pollen are usually insects such as the bee. Flowers pollinated in this way have the following adaptations:

- large, brightly coloured petals to attract insects
- a sweet scent (though flowers of a few plants have an unpleasant smell and are pollinated by flies)
- sticky pollen, which adheres readily to the insect
- nectar, which is sought by the insects for food.

Pollination by the wind. Flowers pollinated by the wind also possess some special adaptations:

- very small petals — large ones would obstruct the movement of the pollen from one flower to another
- a large amount of pollen (this overcomes the large wastage when the pollen is blown about by the wind).

Fruit

The fruit of a plant is the structure developed from the ovary after the flower dies. The seeds mature inside the fruit as it grows. Fruits serve to protect the developing seeds and often help in their dispersal. Not all fruits are suitable for eating. We are all familiar with such fruits as oranges, apples and passionfruit. But pumpkins, gum nuts and Bathurst burrs must also be classed as fruits.

Seed dispersal

The fruits of plants and the seeds in them show a variety of adaptations for dispersal.

In some plants the seeds are easily dislodged and scattered when the fruit opens. The seeds of the tea-tree and the gum tree are dispersed in this way.

Some fruits are eaten by animals and the undigested seeds pass undamaged through the gut. Tomato seeds are often scattered by this method.

Other fruits have hooks on them. The Bathurst burr and the bindi-eye are two of these. These fruits become entangled in the fur of animals and are spread far afield as the animals move about.

Many fruits and seeds are dispersed by wind. The dandelion has a parachute-like structure attached to the tiny fruit. The lightest breeze carries it away. Some seeds have wings that cause them to spin about in the wind. The seeds of the banksia, the spider flower and she-oak are all spread in this way.

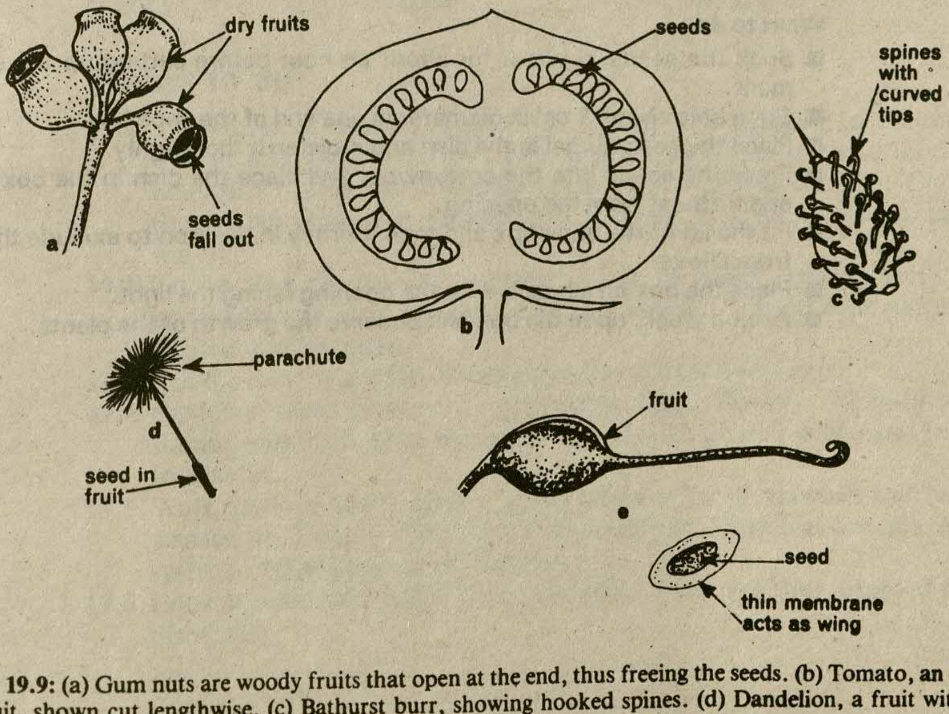


Figure 19.9: (a) Gum nuts are woody fruits that open at the end, thus freeing the seeds. (b) Tomato, an edible fruit, shown cut lengthwise. (c) Bathurst burr, showing hooked spines. (d) Dandelion, a fruit with a parachute. (e) Spider flower, a woody fruit that splits to allow winged seeds to escape.

EXPERIMENT 19.1

Studying varieties of plants and fruit

Each group will need:

- leaves, fruits and seeds of a variety of plants (including *Eucalyptus*)
- razor blade
- hand lens

What to do

- Examine the various leaves. Many Australian native plants have to survive long periods of dry weather. Compare their leaves with those of imported plants such as the tomato and the bean.
- Examine fruits and seeds. Fruits can be both protective and a means of scattering the seeds. Draw up and complete a table describing these two characteristics of the various fruits and seeds you examine.

EXPERIMENT 19.2

Demonstrating a plant's capacity to seek sunlight

Each group will need:

- shoe box
- radish, bean or pea seeds
- adhesive tape
- cottonwool
- petri dish or plastic screw-top lid

What to do

- Soak the seeds in water for about an hour before setting up the experiment.
- Cut a hole about 3 cm in diameter in one end of the shoe box.
- Place the cottonwool in the dish and moisten it thoroughly.
- Press the seeds into the cottonwool and place the dish in the box at the end furthest from the opening.
- Fit the lid of the shoe box and tape it firmly in position to exclude the light from above.
- Place the box on a bench with the opening facing the light.
- After a week, open the box and observe the growth of the plants.

Adaptations in plants

Examples:

- the thick, fleshy stems of a cactus
- the drought-resistant seeds of desert-flowering annuals
- the long, twining stems of lianas
- the large air channels in the stems of water lilies
- the pitchers on the pitcher plant
- the showy petals on insect-pollinated flowers
- the large amount of pollen produced by wind-pollinated flowers
- the hooks on the Bathurst burr
- the wings on the seeds of the banksia.

Each of these adaptations helps the plant to survive in its environment.

Spelling list

banksia
bindi-eye
cactus
canopy
disperse
epiphyte
germinate
nectar
ovule
pollen
succulent
tentacle

Things to do

19.1 The leaves of eucalypts in dry areas are well adapted to conserve moisture. They are narrow, have a thick wax-like coat and tend to hang down with the thin edge of the leaf towards the sun. Check these adaptations for yourself and explain how each helps to save water.

19.2 Try to find sundew for yourself. Look in boggy, shady places or under moist sandstone ledges. Use a hand lens to observe the peculiar structure of the plant.

19.3 Cut the stem of a water lily and look for the air ducts in it.

19.4 Examine some flowers — preferably large flowers. Identify the stamen and style. Slice the ovary in two with a razor blade and look for ovules.

19.5 Walk along a beach after a storm when a lot of seaweed has been washed up. Look for seaweed with holdfasts. Holdfasts are not root systems. What purpose do they serve?

19.6 Look for the seed heads on couch grass. How are they adapted for dispersal?

More questions

19.7 Name some wind-pollinated flowers. List their special features. Do not confuse a wind-pollinated flower with one that produces seeds adapted for scattering by the wind.

19.8 Name some insect-pollinated flowers. List their features.

19.9 Which of the following foods are fruits and which are made from seeds: cucumber, raisins, bread, oatmeal, rice, cornflakes, beans, spaghetti, walnuts, pumpkins and bananas?

19.10 How are the seeds of a strawberry plant adapted for dispersal?

19.11 What are some of the adaptations for survival of the plants in the Australian desert?

19.12 What special adaptation protects a rose bush from grazing by animals?

19.13 Some Australian wildflowers are regenerated by a bushfire — new young plants can be seen growing through the charred soil after rain. Name some of these plants and give the reason for this adaptation of theirs.

Test yourself (chapter 19)

Choose the best answer to each of the following questions and write its letter in your workbook.

1. Three seeds adapted for dispersal by animals are
   (a) bindi-eye, dandelion and passionfruit
   (b) tomato, orange and bindi-eye
   (c) pumpkin, apple and gum nut
   (d) orange, dandelion and Bathurst burr.
2. Two seeds adapted for dispersal by wind are
   (a) rose and dandelion
   (b) gum nut and she-oak
   (c) bindi-eye and dandelion
   (d) dandelion and banksia.
3. The special adaptation that helps flowering plants to survive in Australian deserts is the
   (a) bright colours of the flowers, which attract insects
   (b) tough leaves
   (c) need for heavy rain for germination
   (d) long roots
4. Three foods that are the fruits of plants are
   (a) pumpkin, tomato and potato
   (b) oatmeal, celery and apples
   (c) apples, cucumber and lettuce
   (d) pumpkin, marrow and cucumber.

5. Three foods that are made from the seeds of plants are
   (a) oatmeal, flour and sugar
   (b) bread, spaghetti and honey
   (c) sugar, raisins and oatmeal
   (d) cornflakes, bread and oatmeal.
6. Some plants growing in boggy soil obtain their nitrogen
   (a) by attracting insects
   (b) by absorption from the soil
   (c) by capturing insects
   (d) through tubes in their stems.

20

Cells

One of the first people to use a microscope was Robert Hooke (1635–1733). With it he examined many things. He was amazed by the appearance of thin layers of living matter when seen through the instrument. He found that living things are not solid but are made up of large numbers of small compartments. He called these compartments cells because they reminded him of a number of small rooms.

Hooke did not realize the importance of his discovery and it was not until two hundred years later that it was realized that cells are the small living units that give life to the whole organism.

Examination of cells

An onion bulb is one of the best objects to use for the examination of cells. Several of the white layers are peeled off the bulb and a small portion of the very thin skin separating the thick layers is placed on a microscope slide. A drop of water is added and a cover slip is pressed over the wet skin. Figure 20.1a is a drawing of the appearance of the layer when seen through a microscope that magnifies 600 times. However, a cheap microscope with a smaller magnification is quite adequate for showing the cell outlines.

Figure 20.1b is a drawing of the shapes of cork cells. These shapes can be seen by placing a thin shaving of cork on a

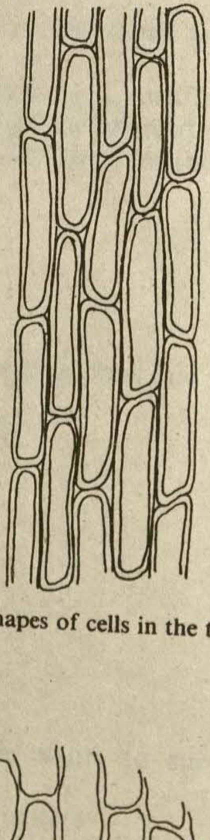


Figure 20.1(a): Shapes of cells in the thin skin of an onion bulb.

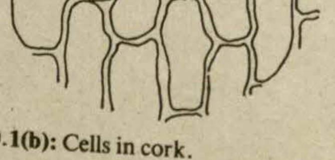


Figure 20.1(b): Cells in cork.

microscope slide and looking at it through a microscope.

It is easy to cut shavings from the stalks and leaves of geranium plants. Figure 20.2 is a drawing of some cells seen in a slice across the soft green stalk of a geranium plant.

So far we have examined only cells from plants. Figure 20.4 shows some magnified animal cells. These were taken from the inside of the cheek of a human.

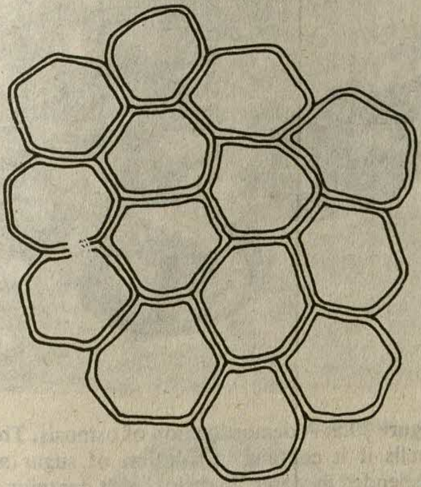


Figure 20.2: Cells in the stalk of a geranium plant.

Sizes of cells

One remarkable fact emerges when cells of many different animals and plants are examined under the microscope. Almost all of them are much the same size, ranging from 100 to the centimetre to 1000 to the centimetre. Because an animal or tree is big, it does not mean that its cells are big. Many of the cells in a whale, for example, are smaller than the cells in a geranium plant.

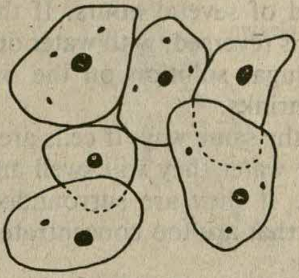


Figure 20.4: Cells seen when scrapings from the inside of the cheek of a human are examined under a microscope.

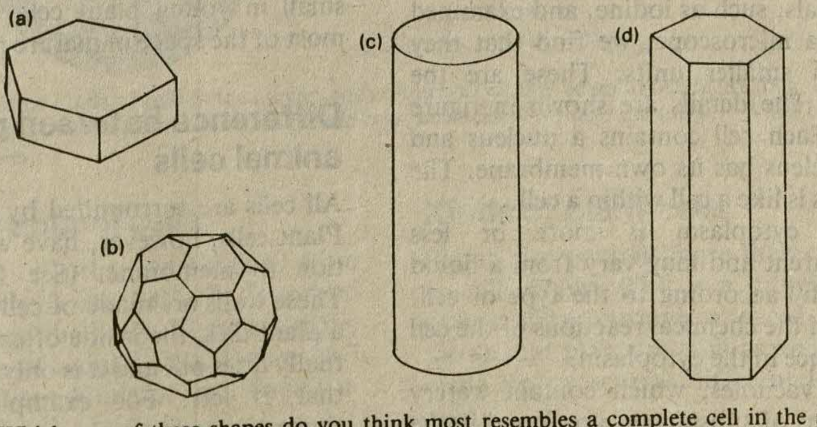


Figure 20.3: Which one of these shapes do you think most resembles a complete cell in the stalk of a geranium plant? (The answer is (d).)

The cell membrane

All cells are surrounded by membranes. A cell is a living thing and must have food to survive. This food passes through the membrane dissolved in water. Wastes pass out of the cell also dissolved in water.

The solutions that feed the cell must be at the correct concentration. One effect of changing the concentration is demonstrated by the experiment shown in figure 20.5. The bag is made from a scrap of cellophane. When it contains sugar solution and is surrounded by water, it swells noticeably during a period of several hours. If the arrangement is reversed, with water on the inside and sugar solution on the outside, the bag shrinks.

In the same way, if cells are surrounded by water they will swell and possibly burst. If they are surrounded by solutions that are too concentrated they will shrink.

This process is called *osmosis*.

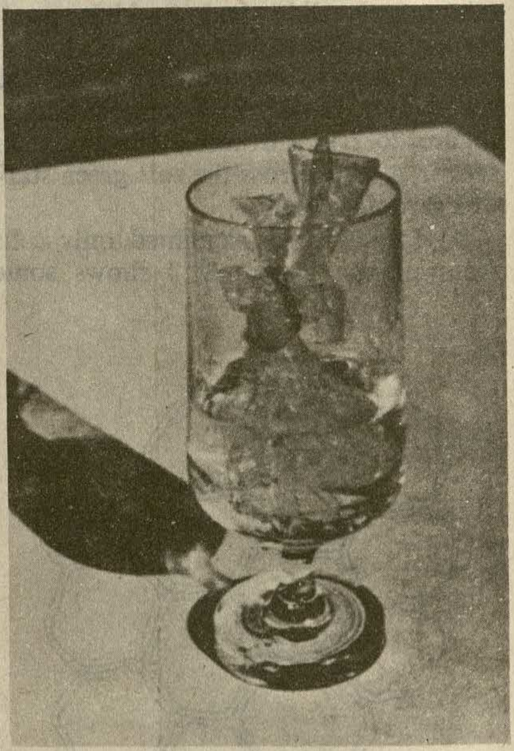


Figure 20.5: A demonstration of osmosis. The bag swells if it contains a solution of sugar and is suspended in water. It shrinks if it contains water and is suspended in a solution of sugar.

Inside the cell

The four samples of cells that we have just examined indicate only the shapes of cells. When cells are stained with chemicals, such as iodine, and examined under a microscope, we find that they contain smaller units. These are the nuclei. The details are shown in figure 20.6. Each cell contains a nucleus and the nucleus has its own membrane. The nucleus is like a cell within a cell.

The cytoplasm is more or less transparent and may vary from a liquid to a jelly according to the type of cell. Most of the chemical reactions of the cell take place in the cytoplasm.

The vacuoles, which contain watery solutions of substances, are found in the cytoplasm. They also are surrounded by their own membranes. Vacuoles are rarely seen in animal cells; they are very small in young plant cells and occupy most of the space in mature plant cells.

Difference between plant and animal cells

All cells are surrounded by membranes. Plant cells, however, have walls in addition to membrane. (See figure 20.6.) These walls are made of cellulose. When a plant dies, the inside of each cell eventually dries out and it is only the cellulose that is left. For example, seasoned timber is made up almost entirely of the walls of dead cells.

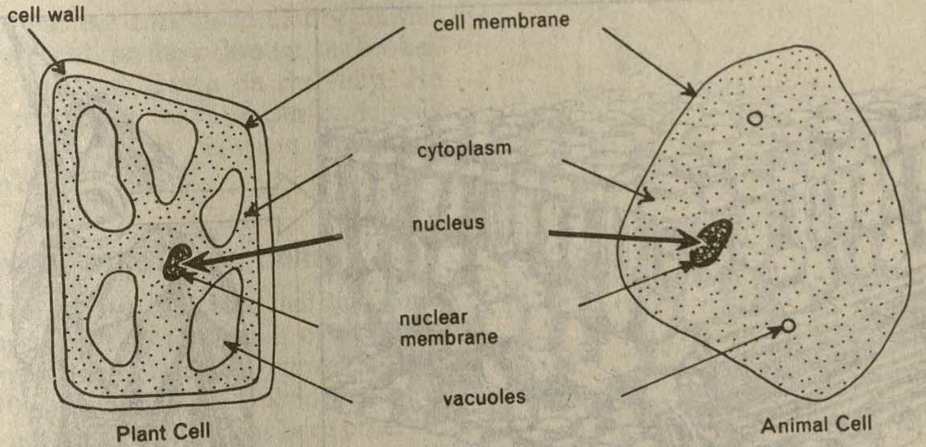


Figure 20.6: Differences between plant and animal cells.

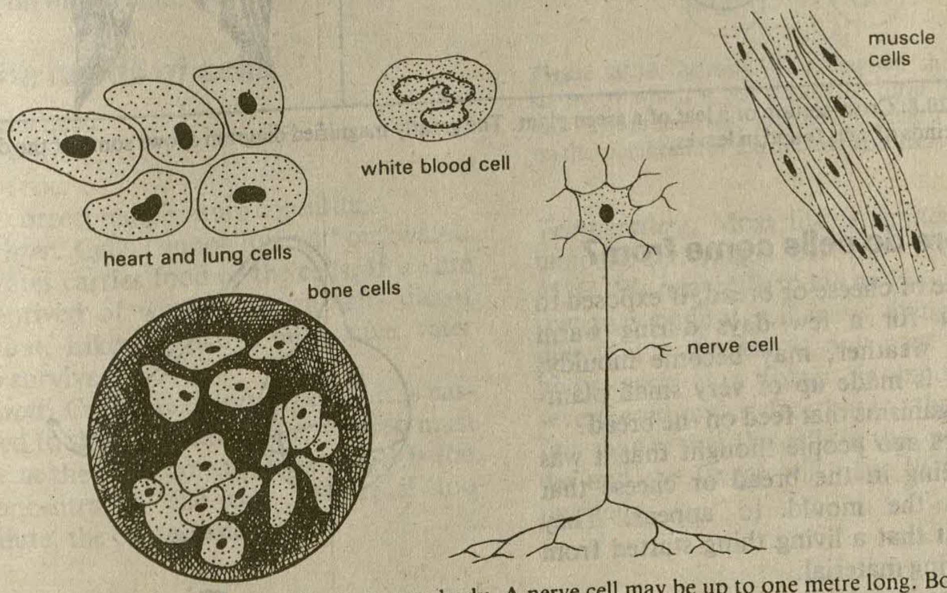


Figure 20.7: Some kinds of cells in the human body. A nerve cell may be up to one metre long. Bone cells occur in the hard structure of the bone. In muscle cells the nuclei occur near the surface. White blood cells have large nuclei.

Kinds of animal cells

The animal cells that we obtained from inside the cheek are flat cells found on the surface of the body. There are many other kinds of animal cells. Figure 20.7 shows different kinds of cells found in the human body.

Kinds of plant cells

Plants also contain more than one kind of cell. Figure 20.8 is a drawing of a cross-section through a green leaf. It shows that plants as well as animals are made up of several different kinds of cells.

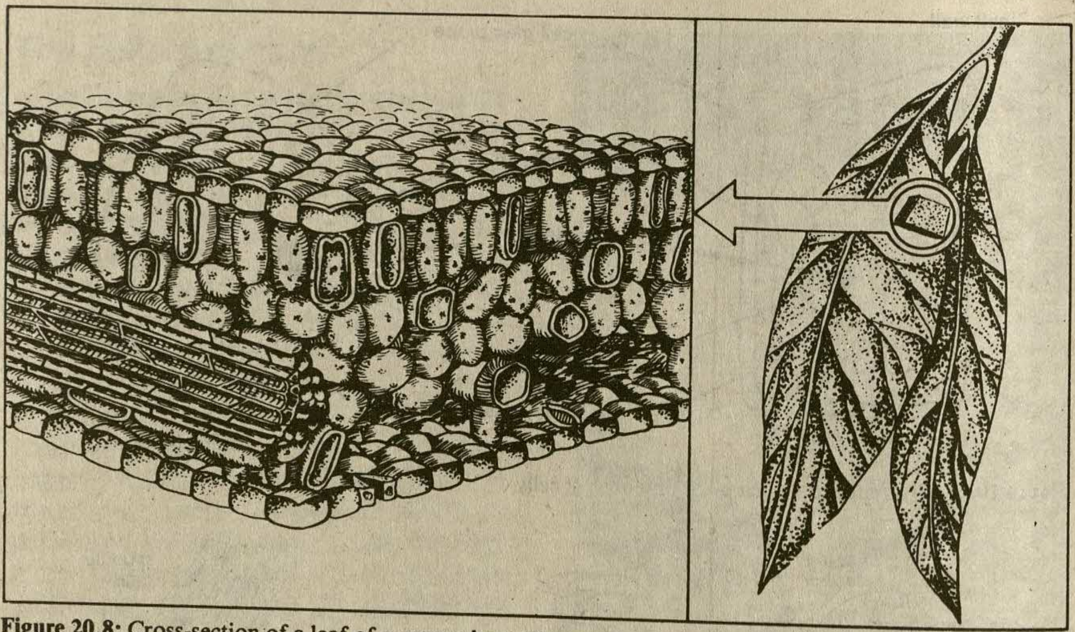


Figure 20.8: Cross-section of a leaf of a green plant. The greatly magnified diagram shows some of the different kinds of cells found in leaves.

Where do cells come from?

A piece of cheese or bread, if exposed to the air for a few days during warm humid weather, may become mouldy. Mould is made up of very small plant-like organisms that feed on the bread.

Years ago people thought that it was something in the bread or cheese that caused the mould to appear. They thought that a living thing started from non-living material.

It was mainly due to the work of the French scientist Louis Pasteur (1822–1895) that this theory was proved wrong. He boiled some soup in a swan-necked flask (illustrated in figure 20.9). This killed all life in the flask. The flask was then allowed to stand for many days; no mould appeared. Next Pasteur broke the neck of the flask so that the surface of the soup was exposed directly to the air. After some days mould appeared on the

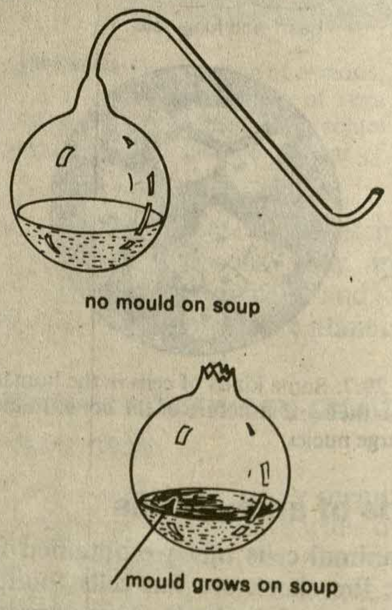


Figure 20.9: The top drawing shows a swan-necked flask of the type used by Louis Pasteur. Spores could not pass up the long curved neck but could easily fall into the flask after the neck was broken off.

soup. Pasteur concluded that organisms had entered the flask through the broken neck and had grown on the soup. He also concluded that life can come only from life — that cells can come only from cells.

Formation of new cells

Pasteur's work indicated that cells come from cells. The formation of new cells from old cells is called *mitosis*. Figure 20.10 shows how a cell divides to form two new cells. Mitosis has been observed under a microscope and has been recorded on movie film.

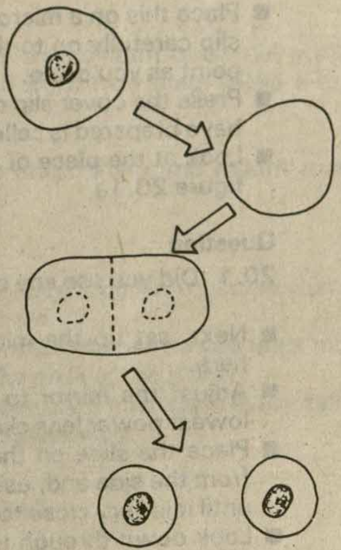


Figure 20.10: Mitosis. This diagram shows the stages by which a cell divides to form two new cells. The process may take hours; while it is going on the membrane of the nucleus dissolves.

The needs of cells

Cells need:

- water
- food
- correct temperature conditions.

***Water*.** Cells cannot live without water. Water carries food to the cells. If we are deprived of water we eventually die of thirst. Likewise plants must have water to survive.

***Food*.** Cells must have food. This is carried to them in water. The solution must be at the right concentration. If it is too concentrated, the cells shrink; if too dilute, the cells swell.

***Temperature*.** Most life is limited to a temperature range between 5°C and 45°C. We heat milk to kill any organisms that may be in it. Likewise, living tissue dies if it is frozen. If any part of our body, such as a finger, is exposed to severe cold and is frostbitten, there is a fair chance that the cells in that part will die and the finger will have to be amputated.

EXPERIMENT 20.1

Looking for onion cells

Each group will need:

- onion bulb
- piece of cork
- razor blade
- microscope slide
- cover slip
- hand lens
- dropper
- microscope

What to do

- Peel back several of the thick layers of an onion bulb.
- Cut off a small piece of the skin separating the layers.

- Place this on a microscope slide and add a drop of water. Lower the cover slip carefully on to the slide, supporting the edge of the slip with a pencil point as you do so.
- Press the cover slip down carefully to force out any air bubbles. What you have prepared is called a *wet mount*.
- Look at the piece of onion with a hand lens. Compare what you see with figure 20.1a

Question

20.1 Did you see any cells? If you did, what can you say about their size?

- Next, set up the microscope on the bench. Your teacher will help you here.
- Adjust the mirror to give maximum light and rotate the turret until the lowest power lens clicks into place.
- Place the slide on the stage of the microscope. Look at the microscope from the side and, using the focusing knob, move the objective lens down until it is very close to the slide.
- Look down through the eyepiece and slowly turn the focusing knob until the image is sharp.

Question

20.2 Draw the outlines of three or four cells in your book. State the magnification of the microscope you used.

- Cut a very thin slice off a piece of cork with a razor blade. Make a wet mount and examine it with a microscope.
- Make a drawing of three or four cork cells.

EXPERIMENT

20.2

Looking at stained cells

Each group will need:

- stalk of a soft green plant such as a geranium
- razor blade
- microscope slide
- iodine solution
- filter paper
- cover slip
- dropper
- microscope

What to do

- Cut a very thin slice across the stalk of the plant.
- Place it on the microscope slide and add a small drop of iodine solution.
- Press the cover slip carefully onto the slice. Take up the surplus solution with a piece of filter paper.
- Examine the slice with a microscope.

Question

20.3 Can you see some cells outlined? Try to identify the cell wall, nucleus and vacuoles. Figures 20.2 and 20.6 may help. Make a drawing of several cells.

- Cut a slice along the length of the stalk. Stain and mount it as before. Examine the slice with a microscope.

Questions

20.4 Do the cells shown in this slice have a different shape from those in the first slice? Sketch some of them.

20.5 Look at figure 20.3. Which one of the shapes do you think most closely resembles a complete cell in the stalk of the plant?

20.6 You probably were not able to identify a nucleus in every cell you saw with the microscope. Can you explain why?

EXPERIMENT

20.3

What does a cell from your body look like?

Each group will need:

- spatula
- slide
- cover slip
- dropper
- iodine solution
- filter paper
- microscope

What to do

- Scrape the inside of your cheek with a clean spatula or the handle of a teaspoon. It is not necessary to press hard when scraping; the actual scrapings will be so small as to be almost invisible.
- Place the scrapings on a microscope slide, stain and mount as before.
- Examine with a microscope.

Question

20.7 Were you able to see several cells? These cells are different from plant cells; they have no cell wall and are not as regular in shape. Sketch several of them.

Cells

1. Living matter is composed of cells.
2. Most cells contain a nucleus and cytoplasm surrounded by a membrane.
3. In addition, plant cells have walls.
4. Cells require water, food and the correct temperature conditions.
5. Cells can grow only from cells.
6. Mitosis is the division of cells to form new cells.

Spelling list

cell
cellophane
cytoplasm
magnification
membrane
microscope
mitosis
nucleus
organism
osmosis
stalk
vacuole

Things to do

20.7 Cut an orange in halves across the direction of the stem. Look for cells in each sector. These cells are unusual because of their size.

20.8 Examine some blood on a microscope slide. Take care to be very clean as you do this experiment, to avoid infection. Clean the top of your finger by swabbing it with methylated spirits. Press your finger on the bench and nick it at the base of the nail with a sterile scalpel. Place a drop of blood on a microscope slide and smear it across the slide using the edge of a second slide. A cover slip is unnecessary.

You will find most of the cells are yellow and round. Strangely, these cells give blood its red colour.

20.9 Examine some skin cells by taking a small piece of skin from your hand or the sole of your foot. Stain and mount as before.

20.10 Look up at the sky. Often you see small dark spots move across your field of vision — they move as your eyes move. These are probably caused by a group of red blood cells moving in front of the retina of your eye.

20.11 Look at a drop of pond water under the microscope. You may be able to see single-celled animals such as paramecia (singular: paramecium) or simple plants such as algae.

More questions

20.12 Why is tinned meat heated when it is sealed in cans at the meat works?

20.13 What is an amoeba? How does it feed?

20.14 How does a plant or animal become larger as it grows?

20.15 Why does the dead stalk of a plant stand upright while a piece of rump steak, say, is quite flexible?

20.16 How does a cut in your skin heal? Is the gap filled with new cells? What causes the cells to stop reproducing once the cut is healed?

20.17 Some cells have a life of only a few hours; others live for years. Look up library books to find out how long skin cells, blood cells and brain cells live. Are cells replaced when they die?

Test yourself (chapter 20)

Questions 1 and 2 refer to figure 20.11, which shows some thin pieces of living material as seen through a microscope. Write the answers in your notebook.

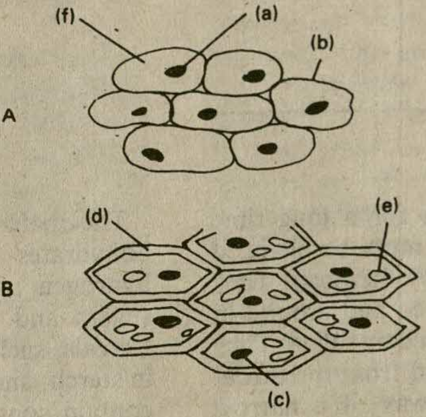


Figure 20.11

1. Which piece, A or B, came from an animal?
2. Name the parts (a), (b), (c), (d), (e) and (f).

Choose the best answer to each question from 3 to 5 and write its letter in your workbook.

3. As a plant grows, its cells
   (a) increase in number
   (b) become longer
   (c) become bigger
   (d) become thicker.
4. The main structure possessed by a plant cell but not by an animal cell is a
   (a) membrane
   (b) nucleus
   (c) wall
   (d) vacuole.
5. "Blood is a clear liquid containing millions of red cells." We know this statement is true because:
   (a) blood is red
   (b) the blood could not do its work without cells
   (c) all animals have cells in their blood
   (d) the cells can be seen under a microscope.

21

Food and digestion

Scientists have known for a long time that the food we eat must be changed before it can be used by the body. They knew that it was chewed and ground in the mouth and lubricated by saliva. They knew also that it passed from the throat into the stomach by way of a narrow channel. But they did not know what happened once the food reached the stomach. For centuries it had been believed that food simply rotted there.

Early last century a human stomach was seen in action for the first time. This was possible because of a shot-gun accident, which blew a hole in a man's side. The man lived on with the hole in his side, and this accident supplied a lot of information about what happened to the food inside the stomach.

In this chapter we will discuss foods and the manner in which they are digested so that the body can use them.

Food

Energy foods

Energy is used in all our movements. We get this energy from the food we eat. Our food also has to supply energy to keep internal organs such as the heart and intestines working. As well, our food supplies heat to warm our bodies.

The main energy foods are the carbohydrates (compounds of carbon, hydrogen and oxygen). These are the sugars and starches. (See table 21.1.) Cereals, such as wheat and rice, are rich in starch, and many fruits and vegetables contain considerable amounts of sugar. Sweets, honey, syrup and jam are also rich in sugar.

Table 21.1: Carbohydrates

Carbohydrate	Some foods that contain the carbohydrate
glucose	grapes, honey
fructose	grapes, honey
sucrose	sugar from sugar cane or sugar beet
lactose	milk from all mammals
maltose	malt
starch	bread, potatoes, all types of grain (wheat, maize, barley, rice and so on)

Perhaps you have heard a person who is dieting refuse a certain food because "it contains too many calories". If that person had gone metric, he or she would have said of the food, "it contains too many kilojoules". The kilojoule is a unit that measures the energy value of foods. An average teenager uses about 13 000 kilojoules per day — a boy perhaps needing a little more than a girl. A man doing heavy physical work could require as much as 21 000 kilojoules per day. In the world today, however, the majority of people are forced, through poverty, to exist on a daily intake of less than 8000 kilojoules.

If we eat more carbohydrates than we need, much of the surplus is converted to fat and stored in our bodies. This is why people who eat an excess of sugars and starches tend to put on weight. Table 21.2 gives an idea of the energy values of some common foods.

Table 21.2: Energy in foods

Portion of food	Energy content in kilojoules (kJ)
one apple	310
slice of bread	250
tablespoon of butter	420
small slice of cake	420
large boiled egg	420
large orange	420
medium-sized potato	420
tablespoon of sugar	210
20 grams of chocolate	420

Fatty foods — energy reserves

Like carbohydrates, fats are foods that provide us with energy. In fact, a gram of fat will yield twice as much energy as a gram of carbohydrate. Fats are also similar to carbohydrates in composition: they are compounds of carbon, hydrogen and oxygen.

You can probably name a number of fatty foods. They are easy to recognize because of their greasy feel. Butter, margarine, certain types of fish, eggs, cooking oils and most red meats are rich in fats.

Fats are not digested as rapidly as carbohydrates and any unchanged fats are stored in various parts of the body as reserves of energy. These reserves are used when the body is deprived of food for long periods. Stored fat also acts as insulation against cold and helps protect various organs in the body. Have you ever noticed the protective layers of fat around a sheep's kidney?

There is a theory that certain types of fats called saturated or hard fats increase the possibility of a person's having a heart attack. Butter, ice cream and meat contain hard fats. So-called soft or unsaturated fats are common in fish and vegetable oils. Margarine, a substitute for butter, is made from soft fats. Because fats in general are slowly digested they satisfy hunger for longer periods than do the more easily digested carbohydrates.

Body-building foods

A large part of the tissues in our bodies is almost entirely composed of proteins. The skin, muscles and blood cells are examples of such tissue. Proteins are very complex substances. Like the carbohydrates, they contain carbon, hydrogen and oxygen. However, proteins also contain nitrogen and small quantities of certain other elements, such as sulphur and phosphorus. One protein in the blood contains iron.

Foods rich in proteins are essential to a balanced diet. The body needs proteins for the growth of new cells and for the repair and replacement of older cells. Milk, some vegetables, meat, chicken, fish, cheese, grains and nuts are some foods rich in proteins.

Proteins that are not used to build new cells may be used to provide energy. One gram of meat, for example, can provide the same amount of energy as a gram of bread. However, bread is a much cheaper source of energy than meat.

Foods containing minerals

Plants absorb minerals from the soil into various parts of their structures. Animals obtain the minerals they need by eating plants or other animals. A good diet will contain a variety of foods so that the body obtains all the minerals it needs for good health. Table 21.3 gives details of some of the elements in minerals the body absorbs and what they are needed for.

As well as the four listed in table 21.3, there are many other elements required by the body. Two of these are sodium and potassium; elements such as copper and cobalt are needed in very small amounts.

Foods containing vitamins

Vitamins are necessary for the proper working of the body. However, our bodies require only very small amounts of vitamins and, if we eat a variety of foods, we can be sure of obtaining all the vitamins we need.

Some people attempt to increase their vitamin intake by taking vitamin pills. However, there is no scientific evidence to indicate that additional quantities of vitamins will improve our health or resistance to disease. On the contrary, it has been established that in the case of vitamin A excessive intake can be quite harmful.

Table 21.4 lists some of the more important vitamins and gives some details about them.

Other things required in a diet

Water. Water makes up about 70 per cent of the weight of the human body. The foods discussed in this chapter are carried to the cells of the body in solution. Water is continually leaving the body — in the air we breathe out, in the sweat from the skin and in urine from the kidneys. The average adult needs about two litres of water daily to replace the water the body loses.

Roughage. Roughage is fibrous material such as the substance forming the cell walls of plants. Humans cannot digest this roughage and it is eliminated as faeces. Roughage assists the process of digestion. Some scientists have suggested it may protect against stomach cancer.

Table 21.3: Foods containing minerals

Element	Source	Needed for
calcium	dairy foods, green vegetables, cereals	growth of bones and teeth, clotting of blood, beating of the heart, action of muscles, functioning of nerves
iron	liver, egg yolk, dried fruits	formation of haemoglobin (the red colouring matter in the blood)
iodine	fish foods, drinking water	the thyroid gland, which controls cell respiration
fluorine	drinking water	prevention of tooth decay

Table 21.4: Foods containing vitamins

Vitamin	Source	Needed for	Result of deficiency
A	green and yellow vegetables, fish, liver, butter	proper working of the eye	blindness
B	yeast extract, whole-grain cereals, wholemeal bread, meat, eggs	healthy skin and nerve tissue	beri-beri, pellagra, other diseases of skin and eye
C	citrus fruits, tomatoes	cell respiration	scurvy
D	butter, fish, egg yolk, liver	healthy bone formation	rickets

A balanced diet

It is strange that in Australia, a country with plenty of food by world standards, many people are undernourished. Some of this undernourishment may be due to poverty, but much of it is due to ignorance: people do not eat the right foods.

So much of our food is purified and refined that there is a danger we may not be getting enough of the materials required for good health (such as roughage, vitamins and minerals). Unfortunately this refined and packaged food is often easy to prepare and serve and is therefore popular.

Biscuits, cake and sweets may provide us with energy, but eaten to excess they are converted to fats and stored in the body. These foods should have an unimportant place in the diet.

Digestion

Pieces of meat or bread, peanuts or peas will not dissolve when shaken in water in a test tube. It is therefore obvious that they must be changed after we eat them before they can be dissolved in the watery solutions of our bodies, and assimilated. The process of breaking food down into smaller particles and simpler substances within the body is called *digestion*.

The alimentary canal

The changes that our food undergoes occur in a tube that extends from the mouth to the anus. This tube is the alimentary canal. Figure 21.1 shows the various parts of the alimentary canal together with the organs concerned with digestion.

The digestive process occurs in various parts of the alimentary canal.

The mouth. The front teeth are used for biting off pieces of food. The back teeth are used for grinding the food into a paste. The food is mixed with saliva from the salivary glands. This lubricates it so that it can be swallowed easily. The saliva contains a special substance, called an enzyme, that helps to break starch down to sugar. Question 21.3 in "Things to Do" is about saliva and its effect on food.

When the food is ready for swallowing the tongue pushes it to the back of the mouth to the oesophagus. The epiglottis closes over the windpipe to stop food "going down the wrong way". Food is passed along the oesophagus by muscular action. This squeezes it towards the stomach.

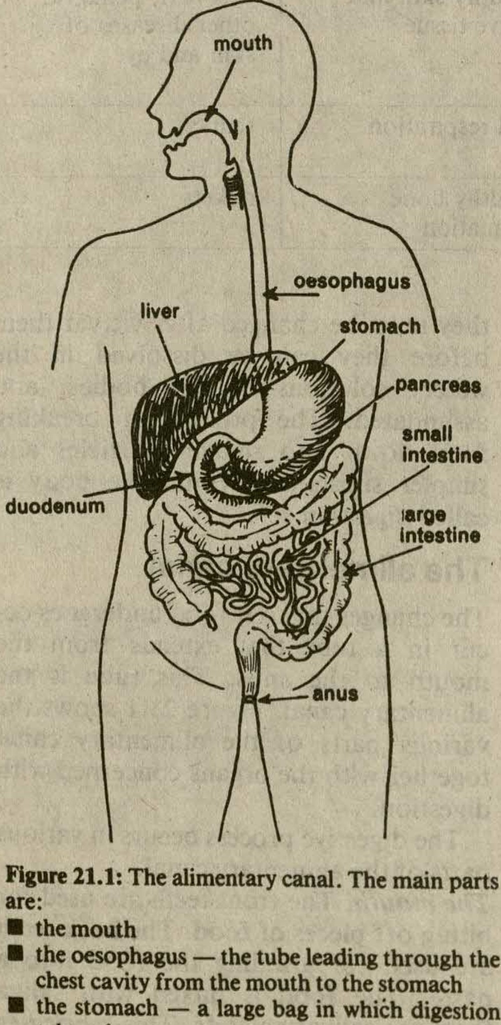


Figure 21.1: The alimentary canal. The main parts are:

- the mouth
- the oesophagus — the tube leading through the chest cavity from the mouth to the stomach
- the stomach — a large bag in which digestion takes place
- the duodenum — the upper part of the small intestine, where digestion is completed
- the small intestine, from which food is absorbed through the walls into the bloodstream
- the large intestine, where the remainder of the food is decayed
- the anus.

The stomach. The stomach produces digestive juices, which consist of hydrochloric acid and enzymes. Muscles in the walls of the stomach keep the food turning over so that it is well mixed with these juices. They act on the food for several hours, starting the digestion of proteins and fats. The lining of the stomach is coated with mucus that stops the juices attacking the walls. The food passes from the stomach into the small intestine.

The small intestine. Two narrow tubes lead into the duodenum, the upper part of the small intestine. One of these tubes brings bile from the liver to emulsify fats, the other brings pancreatic juice from the pancreas. This juice, together

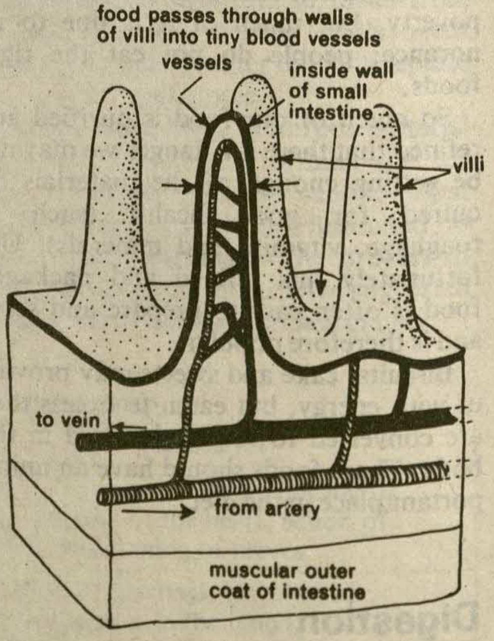

food passes through walls of villi into tiny blood vessels
vessels
inside wall of small intestine
villi
to vein
from artery
muscular outer coat of intestine

Figure 21.2: The projections on the inside wall of the small intestine are called villi. Food particles pass through the walls of the villi into tiny blood vessels and so into the bloodstream.

with enzymes made by the walls of the intestine, completes the digestion with the following results:

- The carbohydrates are converted to glucose.
- The proteins are converted to amino acids.
- Part of the fats is converted to fatty acids, part remains unchanged.

The digestive juices are alkaline and they neutralize the acidic food coming from the stomach. The food spends about four to eight hours in the small intestine. The particles of food at this stage are small enough to pass through the walls into the blood. Figure 21.2 shows part of the small intestine with the tiny projections through which the particles of food pass.

***The large intestine*.** What remains of the food solution spends ten to twelve hours in the large intestine. During this period it loses large quantities of water and some more nutrients. Finally bacteria decay the remains of the food in the colon. The contents of the intestine become a semi-solid mass called faeces. This is passed out through the anus.

EXPERIMENT
21.1

Testing foods for starch

Each group will need:

- various foods such as biscuit, bread, potato, banana, apple, pear, parsnip
- iodine solution

What to do

- Place a drop of iodine solution on each sample. If any starch is present it will turn almost black when the iodine is added.
- Tabulate your results listing the foods tested; state whether or not they contained starch.

EXPERIMENT
21.2

Testing various foods for the presence of fats

Each group will need:

- various samples of food such as peanut butter, meat, chicken, banana
- piece of brown paper

What to do

- Cut the brown paper into small squares and label each square with the name of the food to be tested.
- Press each sample of food hard onto the paper, so that it becomes moist, and then allow the paper to dry.

Question

21.1 Did you notice that in the case of peanut butter a grease spot was left on the paper? If this spot is held up to the light it appears translucent, that is, it allows some light through. This is a test for fat.

- Tabulate your results indicating those foods that gave a positive test for fat.

EXPERIMENT 21.3

Testing for protein

Each group will need:

- egg white (which is rich in protein)
- fingernail clippings, hair
- test tube
- test tube holder
- ammonium hydroxide
- concentrated nitric acid
- Bunsen burner

What to do

- Place a little egg white in the test tube.
- Add a few drops of concentrated nitric acid. Be careful; nitric acid is very corrosive on skin.
- Heat the liquid gently until it boils.
- When it has cooled add a few drops of ammonium hydroxide.

Question

21.2 Did a deep yellow colour form? This is a test for protein.

- Repeat the test using fingernail clippings and hair. Tabulate your results.

EXPERIMENT 21.4

Searching for minerals in food

Each group will need:

- some dried breadcrumbs, pieces of cheese, etc.
- crucible
- pipeclay triangle
- tripod
- Bunsen burner

What to do

- Place the food sample in the crucible and heat strongly. At first the food will char, but continue heating until only grey ash is left. This ash is the mineral content of the food.
- Repeat the test with other samples of food.

Food and digestion

1. A well balanced diet contains:
   - carbohydrates
   - proteins
   - fats
   - minerals
   - vitamins
   - water
   - roughage.
2. Digestion:
   - starts in the mouth
   - continues in the stomach
   - is completed in the duodenum.
3. Food passes into the bloodstream through projections on the walls of the small intestine.

Spelling list

alimentary
breathe
carbohydrate
digestion
duodenum
emulsify
enzyme
epiglottis
faeces
fibrous
glucose
kidney
kilojoule
lubricate
mucus (noun)
neutralize
nourish
oesophagus
protein
roughage
saliva
starch
stomach
variety
vegetable
vitamin

Things to do

21.3 Digestion of starch begins in your mouth. Boil some starch paste grains in water. Place a small drop of the liquid on your tongue and allow it to mix with your saliva. After a couple of minutes you should notice the starch develops a sweet taste, as it is changed into sugar by the saliva.

21.4 Shake a little cooking oil with water. Then add a little soap. Notice the difference when you shake again. Here the soap is doing the same job as the bile that emulsifies fat in the duodenum.

21.5 Obtain some tripe from your butcher. This is part of the alimentary canal of a cow. Notice the many small projections, which increase the surface area for the absorption of food that has been digested.

21.6 Read the labelling on some food wrappers to find out what additional substances have been added to the food. Make a class collection of wrappers and find out why all these substances have been added to the various foods.

21.7 Test various foods for glucose by using Testape. First use Testape on a glucose solution, then on pastes of various foods.

More questions

21.8 Why is glucose given to athletes and invalids?

21.9 What sort of food would you take for a day's mountain-climbing?

21.10 There are six classes of foods that can be used by our bodies. Can you name them? Give some examples of foods that are rich in these substances. Which classes of foods provide the most energy?

21.11 Refer to library books to find out about scurvy — what kind of disease it is, the problems it created for early navigators and how it was eventually overcome.

21.12 Refer to library books to find out more about the liver. List the various things it does in your body.

21.13 You hear someone make this statement, "In the past, cannibalism has occurred in some areas of the world because of a shortage of protein." What are you going to say in reply?

21.14 Eskimos live in Arctic regions where, for at least six months of the year, there were (before modern transport methods) no vegetables or fruit. In some way the Eskimos must have been able to obtain a balanced diet. How did they do it?

21.15 What was the diet of the Australian Aborigine before 1770? Was it balanced?

21.16 How do carnivores, such as the dog, exist on a diet of meat alone? Can harm be done to a dog by feeding it cooked meat alone?

Test yourself (chapter 21)

Write the answers to questions 1 and 2 in your workbook.

1. Look at the following list of foods:
   apple, butter, meat, potato.
   Which of these foods is particularly rich in:
   (a) protein
   (b) fat
   (c) carbohydrate?
2. Name the body parts marked (a) to (h) in figure 21.3.

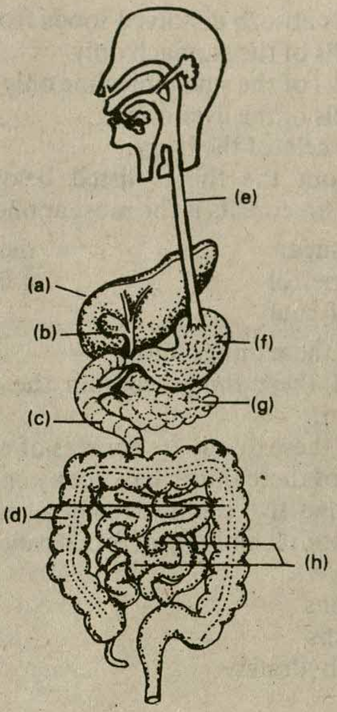


Figure 21.3

In questions 3 to 8, choose the best answer and write its letter in your workbook.

3. A certain food contains the elements carbon, hydrogen, oxygen and nitrogen. The food is a:
   (a) protein
   (b) fat
   (c) sugar
   (d) starch.
4. Of the following substances, which are not used as sources of energy by living things?
   (a) starches
   (b) vitamins
   (c) proteins
   (d) fats.
5. If equal weights of the following substances are "burned" in the body, the largest number of kilojoules is produced by:
   (a) carbohydrates
   (b) fats
   (c) vitamins
   (d) mineral salts.

6. Which cells absorb dissolved foods from their surroundings?
   - (a) the cells of the stomach only
   - (b) the cells of the small intestine only
   - (c) the cells of the liver only
   - (d) all the cells of the body.
7. Think about the things listed below, then indicate which of the suggested statements is the most applicable.

   a kilo of sugar
   a litre of petrol
   a tonne of coal
   the sun
   a litre of peanut oil

   - (a) All of these things burn.
   - (b) All of these things contain the elements carbon, hydrogen and oxygen.
   - (c) All of these things are sources of energy.
   - (d) Each of these things has a constant volume.
8. A boy grows five centimetres in a year. The new material in his body has been built mainly from foods called
   - (a) fats
   - (b) vitamins
   - (c) proteins
   - (d) carbohydrates.

22

Health

How long can you expect to live?

A seventeen-year-old Australian girl can look forward to about sixty more years of life. The life expectancy at birth today is 70 years for males and 77 years for females. Of course it was not always as long as this. At the time of the gold rushes — about 1850 — the average length of life was only about forty years. By 1900 it had increased to about fifty years. Table 22.1 shows how the average length of life has increased through the centuries.

This increase is due to medical progress and improvements in personal and public hygiene. Some countries have benefited from these improvements much less than others. In India, even today, a new-born baby has a life expectancy of only 35 years. A major reason for this low average is that many of the babies die soon after they are born. Can you think of some other reason?

Advantages of a long life span

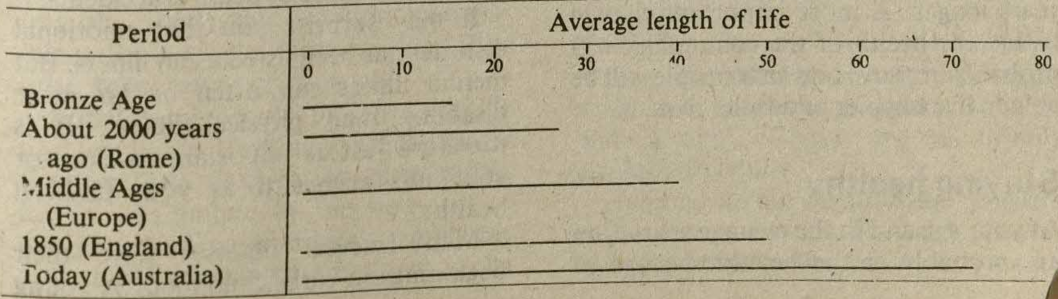
When the average life span is very short many of the potential leaders in every field of human activity die in childhood. As well, most people have only a few years of maturity in which to contribute to the progress of society.

People with a longer life span have more time in which to learn and gain experience. Many of our community leaders are in the 50–70 age group. Would you agree that this is the best age for wise and vigorous leadership? Has anyone under thirty ever been prime minister in this country?

Is the life span likely to increase?

As stated earlier, the average life span in Australia at present is over 70 years. A proportion of the population, of course, die younger and others live longer. A

Table 22.1



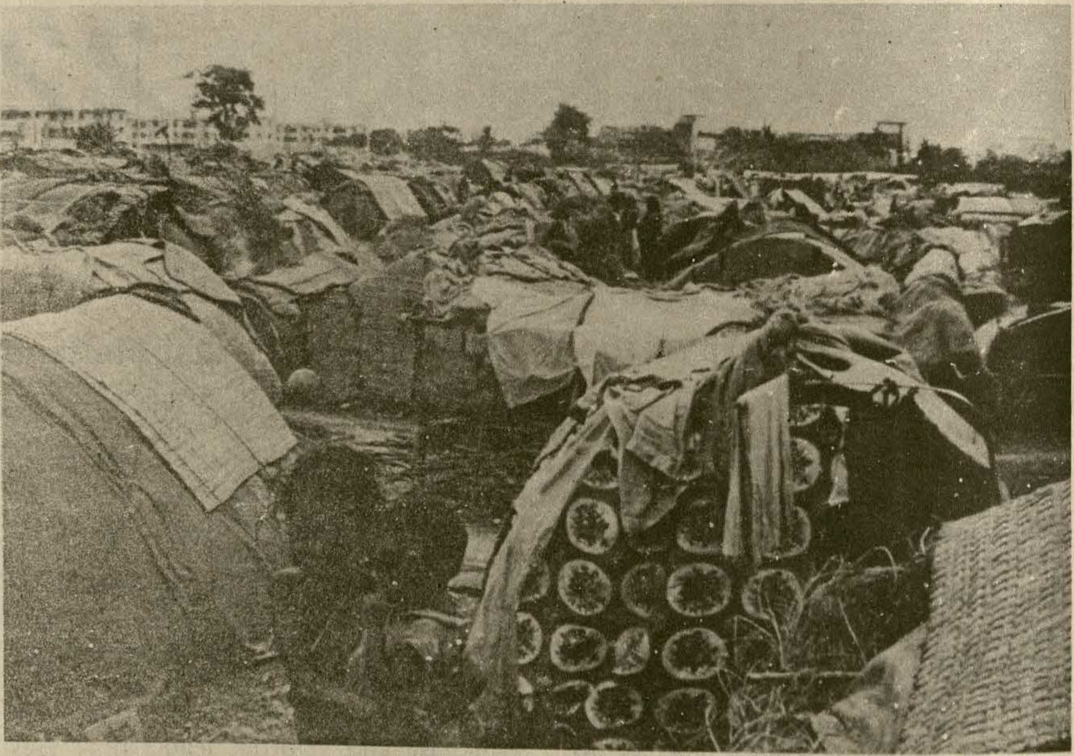


Figure 22.1: A Bangladesh refugee camp. What chance would a new-born baby have of surviving and growing into a healthy adult under these conditions? The average life span here would probably be much less than 30 years.

number reach the age of 90 and some even 100. Does it mean, because the life span is increasing, that eventually some people will live for 120 or even 150 years? It seems hardly likely. The evidence indicates that 90–100 is about the limit.

What may happen is that fewer younger people will die and that people in the 60–70 age group will live a few years longer. A more important change is that the health of the community will probably improve and that people will be able to live happier and fuller lives.

Staying healthy

At your age and in the teenage years, you are probably at the healthiest stage of your life. By now, antibodies that fight off many of the less serious diseases of mankind have been produced in your body and, no doubt, you have been vaccinated against the more serious diseases such as diphtheria and polio. The commonest illnesses likely to affect teenagers are lung ailments, skin problems, gastric ailments and emotional disorders. The commonest cause of death is accidents.

It may surprise you that emotional disorder has been listed as an illness. But mental illness can often be far more disabling than physical illness. It is therefore just as important to care for your mental health as your physical health.

Many mental illnesses have their beginnings in early childhood. A young child needs love and affection and, if deprived of these, it may have emotional problems as it grows older.

A person in a good state of mental health enjoys good personal and social relationships with other people. He does not brood about himself and enjoys his work and recreation. He realizes that constant worry about health is itself unhealthy. Sigmund Freud, a famous psychologist, once said that a mentally healthy person is one who can love and work.

If a person is mentally ill it is important that he has someone with whom he can talk. In some cases medical help may be necessary. Most mental illnesses can be relieved or cured by treatment by medical people specially trained in that field.

Rules for staying healthy

1. Eat properly. In chapter 21 we discussed the various kinds of foods that are needed for a balanced diet: carbohydrates, proteins, fats, vitamins, minerals, water and roughage. Experiment 22.1 is an investigation into the effects of an unbalanced diet on mice.

Lack of balance in diet can be due to a variety of reasons. People well able to afford proper food may find themselves thoughtlessly eating too much starch and sugar and too little food rich in vitamins and minerals. Poor families often do not buy the foods that contain proteins, minerals and salts because they find other foods are much cheaper.

With many people in Australia the problem is one of eating too much rather than too little. Over-eating causes excess fat to accumulate in the body. It is thought that some overweight people eat excessively because of emotional problems. Eating gives them the satisfaction that perhaps is missing from the other activities in their lives. Of course, being overweight is usually depressing in itself.

There are only two possible ways of reducing weight — by eating less or by exercising more or both. Exercise uses energy that is supplied by the burning of fats within the body.

2. Exercise properly. Vigorous exercise is necessary for a teenager to be healthy.

- With exercise the muscles are kept developed and in good tone. The heart is a muscular organ; exercise therefore strengthens it and the arteries and veins connected to it.
- Exercise helps to keep weight under control.

3. Develop good habits of mental health. This has already been discussed. It means becoming an active member of your group, accepting responsibility and treating others' wishes with as much respect as you would like them to treat yours.

4. Have adequate amounts of rest and relaxation. As a teenager you probably need at least eight hours sleep daily. The amount needed varies from person to person. It is important to rest on a firm bed in a well ventilated room.

The development of interests such as sports and hobbies enables a student to completely relax in his free time. This helps the student to remain fresh and be more efficient at his studies. In this way work and study become far more enjoyable.

5. Understand the risks involved with drugs. The commonest health-damaging drugs are headache powders, tobacco and alcohol. These are all legally available to adults.

Habitual taking of headache powders is the cause of much ill health. If you have headaches continuously it is a sign that something is wrong. You should be treated by a doctor. The taking of powders only deadens the pain temporarily and delays your seeking proper treatment.

Headaches may also be the result of tension. If you think you may be worrying too much, try to work out why, and learn to relax more.

Smoking over a long period damages health. However, it is very difficult to give up smoking once you have the habit. Smoking is addictive.

Alcohol has its place as a beverage with meals and on social occasions. However, some people use it as an escape from facing the problems and worries of everyday life. Others become addicted to alcohol in the same way as a person becomes addicted to the drug heroin. Alcoholism has been described as Australia's greatest health problem.

Alcohol costs the community a great deal. There is the cost of treating alcoholics, but much greater are the costs to families and friends, employers and workmates, and in accidents, particularly on the roads. Fifty per cent of all those killed on the roads were in accidents in which at least one driver had been drinking.

There are other, illegal drugs, the use of which has become a problem in our society. Two of these are marihuana (pot), and heroin.

Although some people believe that marihuana is no more harmful than alcohol, others disagree strongly. There is certainly a risk that a pot-smoker will come to depend on the drug to face life, rather than coming to terms with life himself. As marihuana is illegal, a conviction means a heavy fine; later convictions may mean jail.

Heroin is a dangerous, addictive drug. Most heroin-users started with marihuana or alcohol. Pushers of marihuana will often encourage their users to start on heroin, because they make more money out of heroin. Heroin-users themselves often become pushers to pay for their habit. A person who is addicted to heroin often becomes completely cut off from his family, friends who are not also addicts, and the normal everyday world.

Drugs are treated in more depth in a later book.

EXPERIMENT 22.1

What is the effect of giving mice an unbalanced diet?

Each group will need:

- two mice cages
- sawdust, shavings and drinking water
- two newly weaned mice, preferably of the same sex
- plain cake, rolled oats, meat and lettuce

What to do

- Set up the mice cages.
- Place a wooden cotton reel in each cage for the mice to gnaw.
- Feed one mouse with plain cake.
- Feed the other on a balanced diet of meat, oatmeal and lettuce.
- Clean the cages regularly and remove stale food.

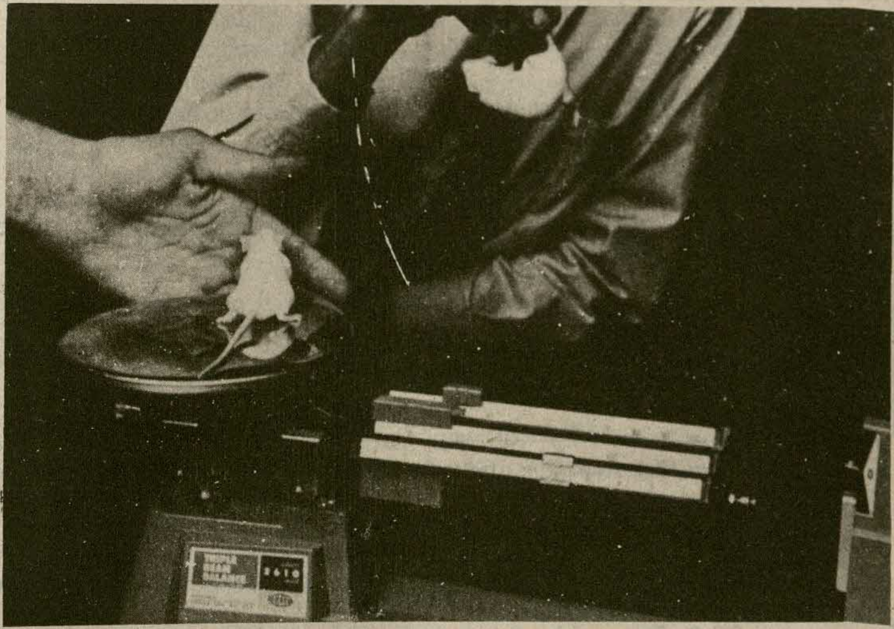


Figure 22.2: Weighing mice. Notice the correct way to pick up a mouse — by the tail.

- Weigh each animal once a week for several weeks.
- Graph your results.
- Write your conclusion.

EXPERIMENT 22.2

What are some of the substances in cigarette smoke?

Each group will need:

- filter pump as shown in figure 22.3 (next page)
- cottonwool
- clamp stand
- glass tube as shown in figure 22.3
- several pieces of rubber tubing
- cigarette
- vessel to catch ash

What to do

- Set up the apparatus as shown in figure 22.3.
- Turn on the tap gently, fit the cigarette, and light it.
- Adjust the water flow so that the cigarette glows as if puffed by a person. After a few seconds turn off the tap.
- Repeat this "puffing" by turning the tap on and off until the cigarette is burnt to within 1 cm of the end.
- Examine the cottonwool.

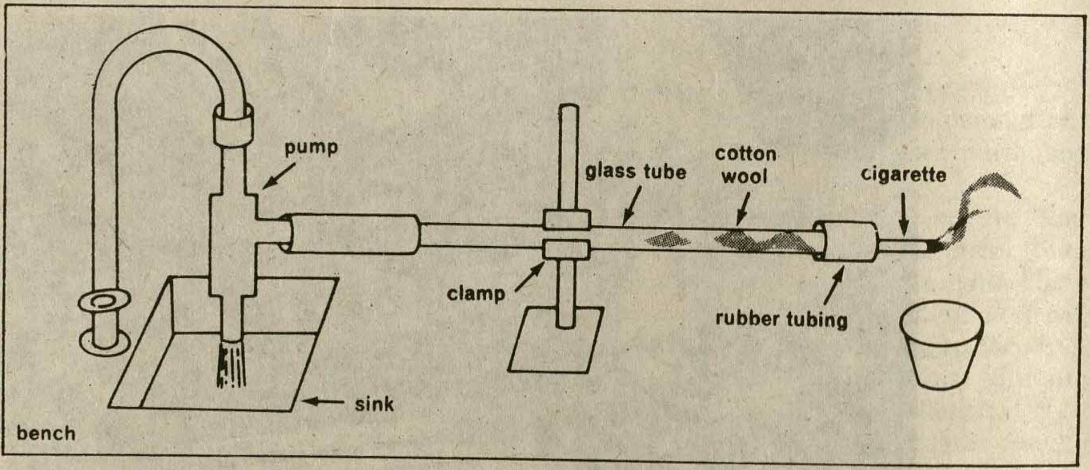


Figure 22.3: Apparatus used to find out what substances are in cigarette smoke.

Questions

22.1 Was anything caught by the cottonwool? If something was, describe its appearance and odour.

22.2 The residue from cigarette smoke is mainly tar and nicotine. Find out what you can about these two substances. What harm can they do?

Staying healthy

1. Eat a balanced diet.
2. Avoid overeating.
3. Have regular exercise, rest and relaxation.
4. Try to develop healthy attitudes to people.
5. Know about drugs.

Spelling list

alcohol
diphtheria
expectancy
habitual
mixture
vaccinate

More questions

22.3 What are the commonest illnesses affecting teenagers?

22.4 Do you agree that accidents are the commonest cause of death among teenagers? Do your classmates agree?

22.5 Some boys have an attitude that it is "sissy" to show affection. What do you think is the cause of their having this attitude? Do you think it is a good or bad attitude?

22.6 Boredom can become a health problem. Whose responsibility is it to prevent boredom in the case of (a) a two-year-old (b) a teenager and (c) an adult? Have a class discussion.

22.7 Why do you see more adults overweight than children?

22.8 What are some of the problems of old age? How should these problems be overcome?

22.9 Why do people start smoking?

22.10 Which aspects of public hygiene have contributed to the high health standards enjoyed in many parts of the world?

22.11 Why do many babies die at birth, or soon after, in India?

Test yourself (chapter 22)

Choose the best answer to each question and write its letter in your workbook.

1. The average life span of the people of India is low because:
   (a) the people do not have enough food
   (b) hygiene is poor in India
   (c) medical services are inadequate
   (d) for all of the above reasons.
2. The main cause of death among young people in Australia is:
   (a) drugs
   (b) pneumonia
   (c) accidents
   (d) diphtheria.
3. Alcoholism has been described as Australia's greatest health problem. Which of the following do you consider the worst effect of alcohol on our society?
   (a) People can become addicted to alcohol.
   (b) Alcoholism causes people to absent themselves from work.
   (c) Alcoholism causes unhappiness in families.
   (d) Alcohol drinking can cause road deaths.

23

Photosynthesis

Years ago it was thought that all nourishment for plants came from the soil. A Dutchman named Van Helmont questioned this and to prove his point planted a young tree in a tub of soil. He tended it for five years and found at the end of that period that it had gained 75 kilograms but its soil had lost only 50 grams. Van Helmont concluded that the tree's gain in weight must have come mainly from the water it received — not from the soil.

Van Helmont was right when he stated that the increase in weight did not come from the soil. He was wrong, however, when he said that it came only from the water the tree had received.

Van Helmont carried out his experiment 300 years ago. It has taken scientists almost all the time since to solve the problem of the gain in weight of the tree.

Materials needed for plant growth

We now know that a plant, unlike an animal, grows on food that it makes itself. Animals either go foraging for their food or wait until it comes to them. Plants, on the other hand, make their own food from materials obtained from the atmosphere and the soil. These materials are:

- carbon dioxide from the atmosphere
- water from the soil
- salts from the soil.

Energy is required to make the food and this energy comes from the sun as light.

Photosynthesis

The basic food made by a plant is glucose. It is made from carbon dioxide and water in the green parts of the plant. Because energy is also required, in the form of light, the process is called photosynthesis.

In the green parts of the plant are special cells that contain small green units called chloroplasts. The green substance that colours the chloroplasts is chlorophyll. Although the chlorophyll does not become part of the glucose, it must be present to allow the energy of the sunlight to do its work. Figure 23.1 is a drawing of a section through a food-producing cell, showing chloroplasts.

At the same time as the glucose is produced, oxygen is also formed. (See figure 23.2.)

The whole process of photosynthesis may be summarized as follows:

$$\begin{matrix}\text{carbon}\\ \text{dioxide}\end{matrix} + \text{water} + \text{energy} \xrightarrow{\textit{chlorophyll}} \text{glucose} + \text{oxygen}$$

Some of the glucose formed is changed into starch and stored in the plant until required.

Photosynthesis is one of the most important chemical reactions taking place on this planet. Animals either eat

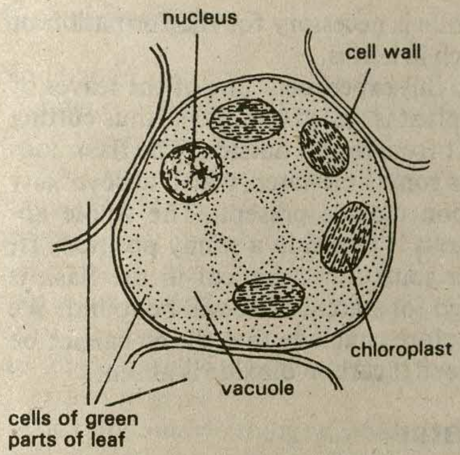


Figure 23.1: A food-forming cell within a plant The parts of the cell that take part in the formation of food are the chloroplasts. These form part of a chain in the manufacture of glucose from carbon dioxide and water.

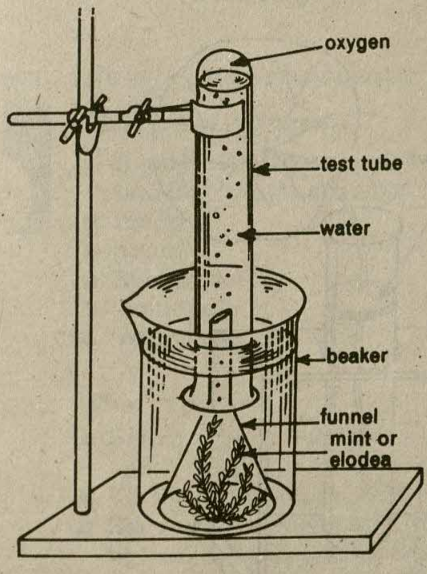


Figure 23.2: The formation of oxygen during photosynthesis. A better yield is obtained if the water in the beaker is first saturated with carbon dioxide.

the plants made by photosynthesis or eat other animals that live on the plants. Photosynthesis also keeps up the supply of oxygen in the atmosphere. This oxygen is used by plants and animals in respiration.

The experiments described in the following paragraphs show some of the requirements for photosynthesis.

Chlorophyll

Variegated plants, such as the Chinese Lantern, have leaves that are partly green and partly yellow. These leaves are useful for this experiment because it can be shown that starch is present only in the green parts of the leaves, that is, in the areas containing chlorophyll.

A fresh leaf is selected and killed by immersing it in boiling water for a minute or so. Next the chlorophyll is removed by soaking the leaf in warm methylated spirits. When dilute iodine solution is added, a dark blue pattern forms on the leaf corresponding to the original green pattern. This shows that starch does not form if chlorophyll is absent.

Light

When a potted green plant is placed in a dark cupboard for twenty-four hours the leaves lose their starch. This shows that a plant uses its starch and that the starch is not replaced if the leaves are in the dark. If the same plant is brought out into the sunlight starch forms again in the leaves after a few hours. This indicates that sunlight is necessary for the formation of starch.

Carbon dioxide

Figure 23.3 is a diagram of an experiment that demonstrates that carbon

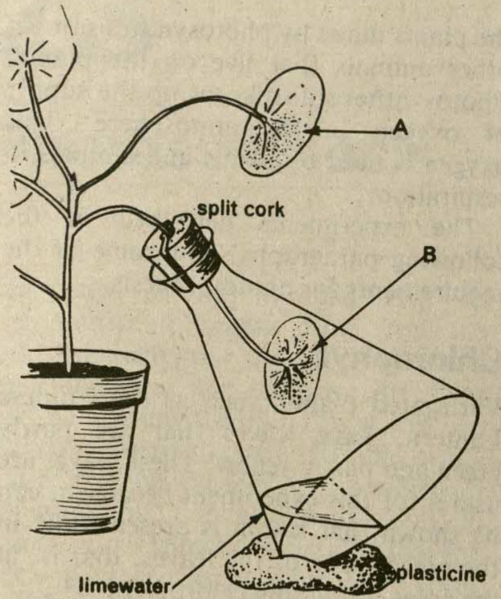


Figure 23.3: Apparatus to show that carbon dioxide is necessary for the formation of starch in leaves. Starch is formed in leaf A, which is exposed to carbon dioxide in the air. Starch is not formed in leaf B because any carbon dioxide near the leaf is absorbed by the limewater.

dioxide is necessary for the formation of starch in leaves.

In this experiment one of the leaves of the plant is sealed in a flask, thus cutting it off from the air outside. The flask contains some limewater, which absorbs any carbon dioxide present. The whole apparatus is placed in a sunny position. If, after some time, the leaf in the flask is tested for starch, none will be found. We therefore conclude that starch cannot be formed if carbon dioxide is absent.

Water

The fact that plants need water is obvious. The farmer looks anxiously to the sky for rain during a drought and we water our gardens when they are dry. The plant obtains its water from the soil. Some of this water is used for photosynthesis. Most of it, however, passes through the leaves and evaporates into the air. This process is called transpiration. (See figure 23.4.)

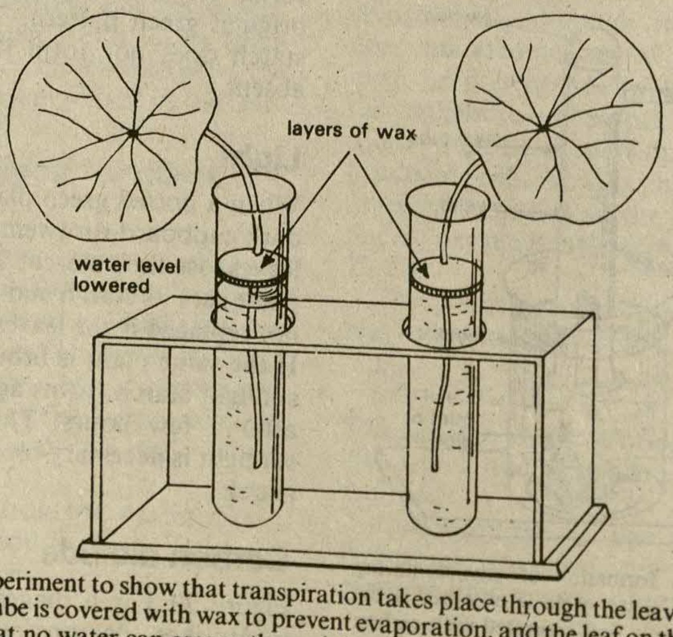


Figure 23.4: An experiment to show that transpiration takes place through the leaves of a plant. The water in each test tube is covered with wax to prevent evaporation, and the leaf on the right is covered with vaseline so that no water can escape through its surface.

Germination

No chapter on photosynthesis would be complete without saying something about the germination of seeds.

Most green plants start from seeds. Figure 23.5 is a photo of a bean seed that has been split in two to show the young plant. As can be seen, the young plant is only a very small part of the seed. The remainder is food — starch, protein and fat, all of which the embryo plant needs as it starts to grow.

The only outside things needed at this stage are oxygen, water and warmth. Seeds will germinate in the dark, so sunlight is not needed and obviously photosynthesis does not take place.

Experiment 23.2 is a study of germination and growth until the first signs of chlorophyll appear.

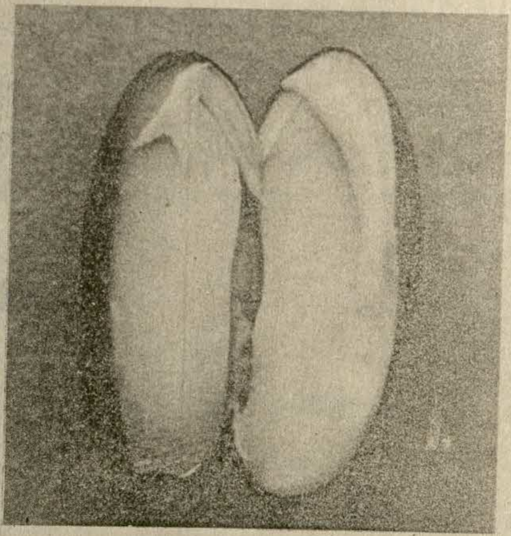


Figure 23.5: A bean seed split in two to show the embryo plant. The two halves of the seed contain the food that will nourish the plant during the first stage of its growth.

EXPERIMENT 23.1

Do variegated leaves contain starch?

Each group will need:

- fresh leaves from abutilon (Chinese Lantern) or similar plant
- two beakers (as shown in figure 23.6)
- tripod
- gauze
- Bunsen burner
- iodine solution
- methylated spirits

What to do

- Select a fresh leaf from a variegated shrub such as an abutilon (Chinese Lantern). Sketch on paper the pattern of the green areas.
- Kill the leaf by placing it in boiling water for about a minute.
- Remove the chlorophyll from the green parts by treating it as shown in figure 23.6 (next page). Make sure you use a gauze on the tripod and keep the Bunsen flame low because methylated spirits ignites easily.
- When the leaf has lost all its chlorophyll, wash it under a tap and then place it in iodine solution for a few minutes.
- Remove it and wash it again.

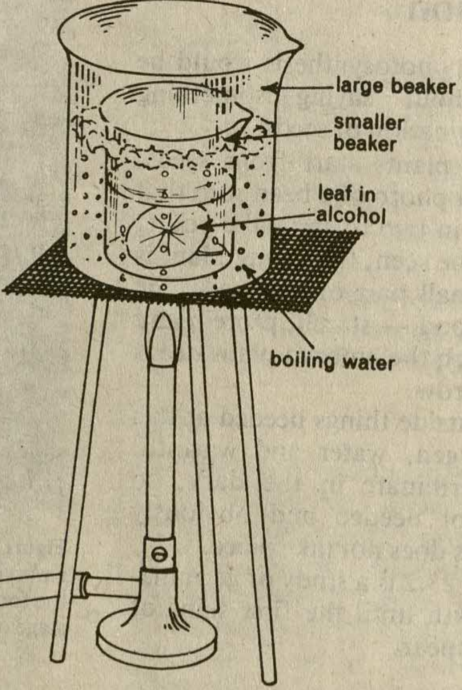


Figure 23.6: Removing chlorophyll from a leaf.

Questions

23.1 Describe any changes that occurred when the leaf was placed in
  (a) boiling water
  (b) hot methylated spirits
  (c) iodine.

23.2 What areas in the leaf turned dark blue?

23.3 What parts of the leaf contained starch?

EXPERIMENT 23.2

Studying the germination of a broad bean seed

Each group will need:

- glass jar
- two broad bean seeds
- sawdust

What to do

- Soak the seeds in water for an hour.
- Fill the jar with sawdust.
- Push the seeds down between the sawdust and the glass, about 3 cm below the surface of the sawdust.

- Water the sawdust and keep it damp throughout the experiment.
- Place the jar in a sunny position.
- Watch the seeds germinating and the young plants growing.

Questions

23.4 Which appeared first, the root or the growing tip of the plant?
23.5 Where did the first leaves form and when did the first signs of green appear?

Photosynthesis

1. Photosynthesis is the absorption of light energy to make glucose from carbon dioxide and water.

$$\text{carbon dioxide} + \text{water} + \text{energy} \xrightarrow{\textit{chlorophyll}} \text{glucose} + \text{oxygen}$$

2. Part of the glucose formed by photosynthesis is stored in the plant as starch.
3. Germination of seeds requires only water and warmth.
4. Photosynthesis does not take place during germination.

Spelling list

chlorophyll
chloroplast
germination
glucose
photosynthesis
transpiration
variegated

Things to do

23.6 Compare the times taken to germinate radish seeds in a warm cupboard and in a refrigerator.
23.7 Drop some radish seeds in boiling water for 10 seconds and then try to germinate them.
23.8 Place a piece of wood on a lawn for several days. Then test the grass underneath for starch. How long does it take the chlorophyll to reappear after the wood has been removed?
23.9 Stand a stick of celery in a beaker of water coloured with red ink. Note the rate at which the coloured water rises in the stem.
23.10 Test seeds of various kinds for starch, protein and fat.
23.11 Suck a fresh young grass shoot that has just been pulled from a plant. Notice the sweet taste — this is sugar.

More questions

23.12 Plants remove carbon dioxide from the atmosphere and release oxygen. Careful measurements show that the amount of carbon dioxide in the atmosphere is slowly increasing. Try to find out why this is happening and what people are suggesting might eventually occur as a result of this increase.

23.13 Photosynthesis has been described as the most important chemical process in the world. Do you think this is an exaggeration? Explain.

Test yourself (chapter 23)

Write the answers to questions 1 and 2 in your workbook.

1. With regard to photosynthesis:
   (a) What is the name of the green pigment required?
   (b) What gas is absorbed from the air?
   (c) How is water, required for the process, obtained?
   (d) What gas is set free during the process?
   (e) What compound is formed as a result of photosynthesis?
   (f) In what part of the plant cell is the green pigment concentrated?
2. Name a substance used to absorb carbon dioxide.

In questions 3 to 5, choose the best answer and write its letter in your workbook.

3. Which of the following pairs of things is necessary for the germination of seeds?
   (a) soil and water
   (b) sunlight and water
   (c) water and warmth
   (d) carbon dioxide and warmth.
4. Photosynthesis is important because:
   (a) it is needed for plant growth
   (b) it makes food for animals
   (c) it keeps up the supply of oxygen in the atmosphere
   (d) all of the above reasons.
5. Most of the carbon taken in by a green plant enters the plant through:
   (a) the leaves as carbon dioxide
   (b) the leaves as sugar
   (c) the leaves as starch
   (d) the roots as water.

24

Respiration

Respiration is one of the most important processes in nature. By this process organisms use food and oxygen to obtain energy for work and growth. Respiration takes place in the cells of organisms.

Respiration may be compared to the way a motor car engine obtains its energy from petrol.

Respiration and the petrol engine

The engine sucks in petrol and air through the carburettor. (See figure 24.1.) The mixture is then burnt in the engine and gives out heat. Part of this heat is used to drive the car but most of it is wasted, and so must be removed. This is done by circulating cold water or air around the engine. The gases formed by the burning of the petrol are carbon dioxide and water vapour; these are blown out through the exhaust.

$$\text{petrol} + \text{oxygen} \rightarrow \begin{matrix}\text{carbon}\\\text{dioxide}\end{matrix} + \begin{matrix}\text{water}\\\text{vapour}\end{matrix} + \text{energy}$$

Respiration in animals

Animals take in food and air. The food is digested to form glucose, which is absorbed by the cells. The glucose reacts with oxygen in the cells to liberate energy, carbon dioxide and water. It must not be thought that the glucose burns in the cells in the simple way that petrol burns in an engine. The reactions in the cell are very complicated and at the same time very efficient. The motor car wastes a lot of its energy; the cell wastes practically none of the energy it generates.

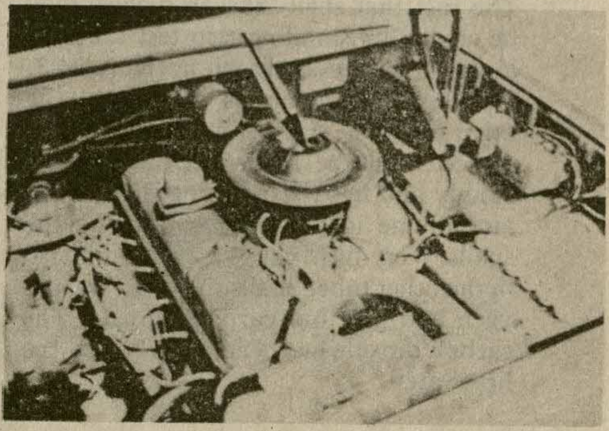


Figure 24.1: A Holden engine. The air cleaner has been removed to expose the throat of the carburettor. This is indicated by the arrow.

The chemical reactions in the cell can be summarized as follows (see also figure 24.2):

$$\text{glucose} + \text{oxygen} \rightarrow \begin{matrix}\text{carbon}\\\text{dioxide}\end{matrix} + \text{water} + \text{energy}$$

We shall now describe several experiments that demonstrate some of the facts of respiration. The first three of these depend on a test for carbon dioxide.

Carbon dioxide may be detected in a mixture of gases by blowing the mixture through limewater. If carbon dioxide is present it is absorbed by the limewater and a white precipitate (chalk) is formed.

Showing that animals use oxygen

The fact that snails absorb oxygen may be shown by standing two test tubes of air in limewater as shown in figure 24.3. One test tube contains snails and the other does not. After some days it will be noticed that the limewater has become cloudy and has risen by one-fifth of the air volume in the tube containing the snails. Very little change will be noticed in the other tube. Snails therefore use oxygen and give out carbon dioxide. The carbon dioxide has been absorbed by the limewater.

Comparing inspired and expired air

The apparatus shown in figure 24.4 can be used to demonstrate that expired air contains more carbon dioxide than inspired air does. After the person conducting the experiment breathes in and out through the apparatus for several minutes, a white precipitate forms in the right-hand bottle while the limewater in the left-hand bottle becomes only slightly cloudy. Since the expired air passes only through the right-hand bottle, we can conclude that it contains more carbon dioxide than inspired air does.

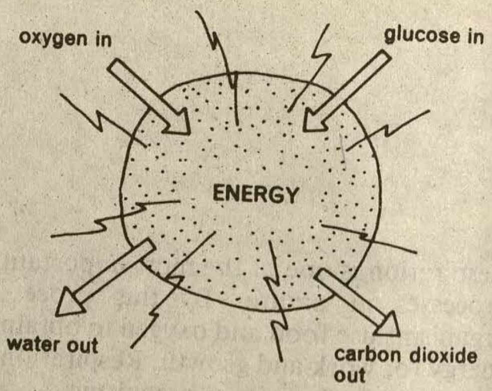


Figure 24.2: Respiration occurs in the cells. Oxygen and glucose in solution diffuse through the membrane into the cell, where they react to produce energy, carbon dioxide and water.

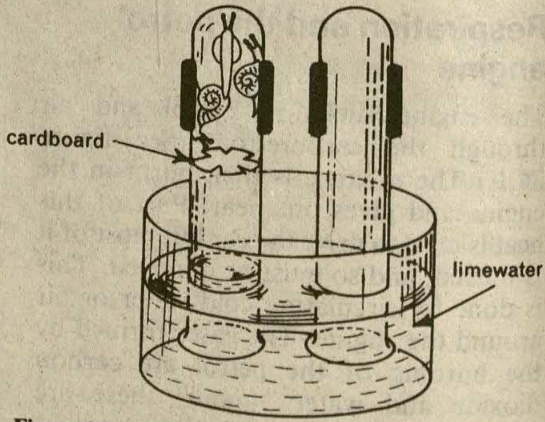


Figure 24.3: Apparatus to show that snails absorb oxygen. The expired carbon dioxide and water vapour are absorbed in the limewater. The level in the left-hand test tube therefore rises, by about one-fifth. There is no rise in the right-hand tube, which is called the control.

Table 24.1 gives a comparison of the composition of air before and after breathing.

Table 24.1: Comparison of the composition of air before and after breathing

You breathe in:		You breathe out:	
nitrogen	78%	nitrogen	78%
oxygen	21%	oxygen	16%
carbon dioxide	0.04%	carbon dioxide	5%
other gases	1% (approx.)	other gases	1% (approx.)

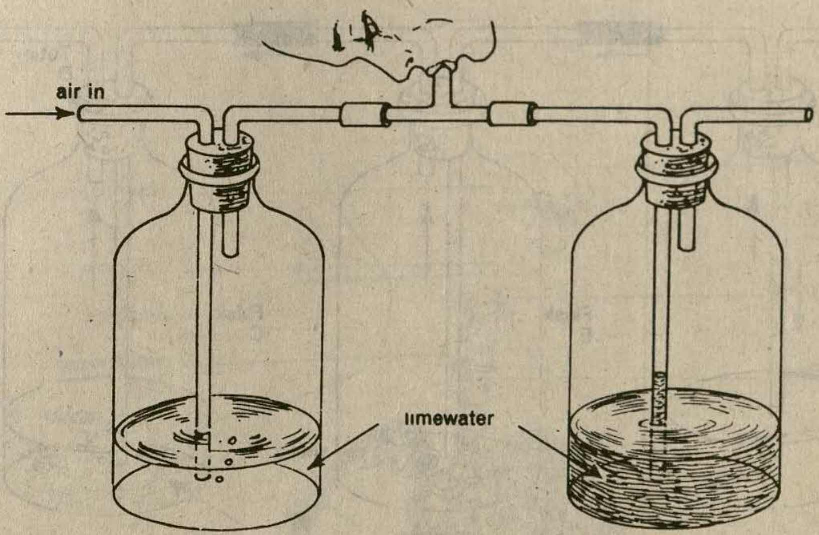


Figure 24.4: An experiment to show that expired air contains more carbon dioxide than inspired air. In the diagram the person is shown breathing in. This reduces the pressure in both bottles. Bubbles of air therefore flow into the left-hand bottle and the limewater rises in the tube in the right-hand bottle.

Water vapour is not included in the table because the amount in the atmosphere varies from day to day.

Testing air exhaled by snails

Figure 24.5 shows a method of finding out whether snails, like humans, breathe out more carbon dioxide than they breathe in. The limewater in the bottle on the right becomes quite cloudy while that in the bottle on the left is barely changed. This shows that snails exhale more carbon dioxide than they inhale.

Expiration of water vapour

If we watch humans or other large animals on a cold morning, we notice that small clouds of condensed vapour form each time the person or animal exhales. We can prove that this condensed vapour is water by testing it with anhydrous copper sulphate.

The exhausts of motor cars also give out clouds of condensed water vapour on cold mornings. On warmer days, this water vapour is absorbed by the air without condensing.

Lungs

Earlier in this chapter we stated that cells absorb food and oxygen and excrete carbon dioxide and water vapour. The oxygen comes from the air; the carbon dioxide and water vapour pass out to the air. This exchange of gases to and from the air takes place in the lungs.

Figure 24.6 is a model of the lungs to show how the diaphragm causes expiration and inspiration. When we push the rubber diaphragm in, the lungs (the balloons) collapse and air is forced out of them. When the pressure of our fingers is taken off the diaphragm and it flattens, air flows into the lungs and they expand.

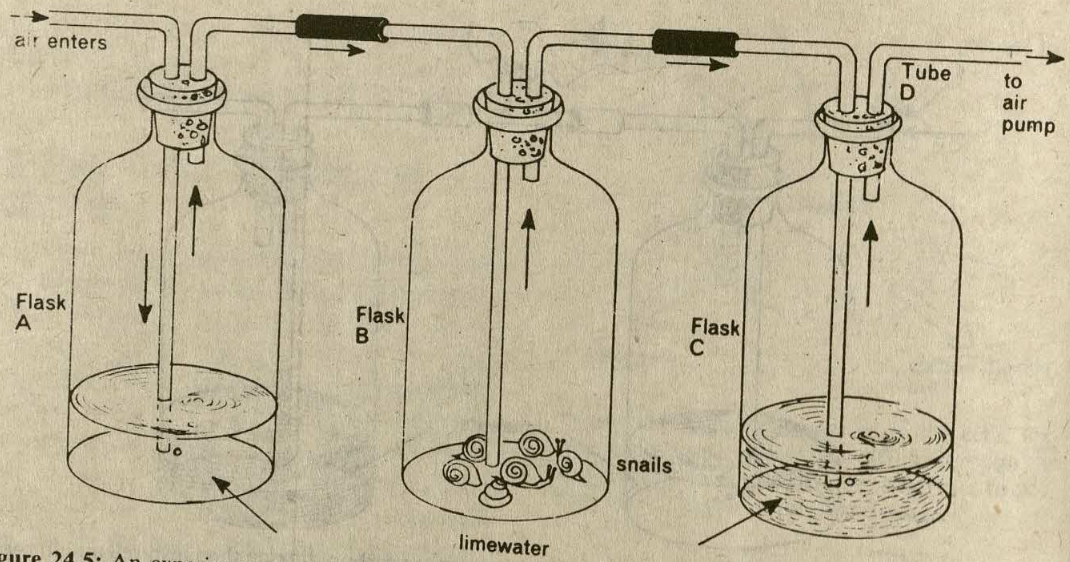


Figure 24.5: An experiment to show that snails exhale carbon dioxide. The limewater in the right-hand bottle is more cloudy than the limewater in the left-hand bottle.

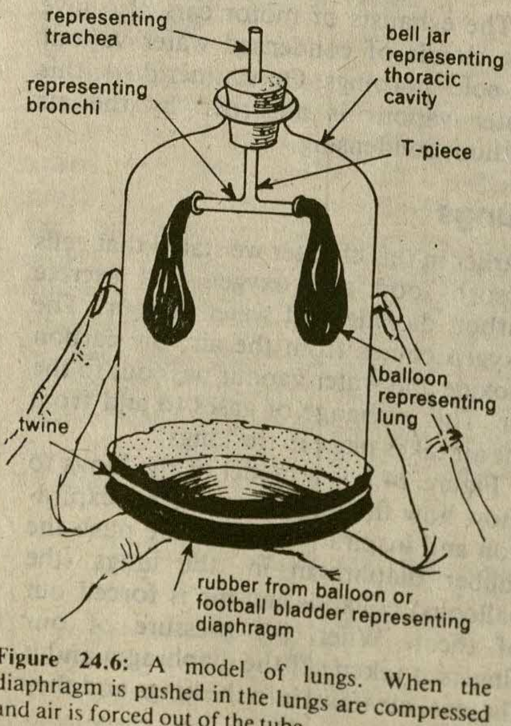

representing trachea
bell jar representing thoracic cavity
representing bronchi
T-piece
balloon representing lung
twine
rubber from balloon or football bladder representing diaphragm

Figure 24.6: A model of lungs. When the diaphragm is pushed in the lungs are compressed and air is forced out of the tube.

When we inhale, the muscles connecting the ribs tighten and lift the rib cage up and out. At the same time the diaphragm contracts, which causes it to flatten. The result of these two movements is an enlargement of the chest cavity that causes air to be forced into the lungs.

Breathing out takes place when both the rib muscles and the diaphragm relax. This causes the ribs to drop and the diaphragm to rise (it is pushed up by the organs beneath). Air is thus forced out of the lungs. (See figure 24.7.)

The exchange of gases takes place in tiny air sacs in the lungs. It is here that oxygen is absorbed into the capillaries during inspiration and carbon dioxide and water vapour are given off during expiration.

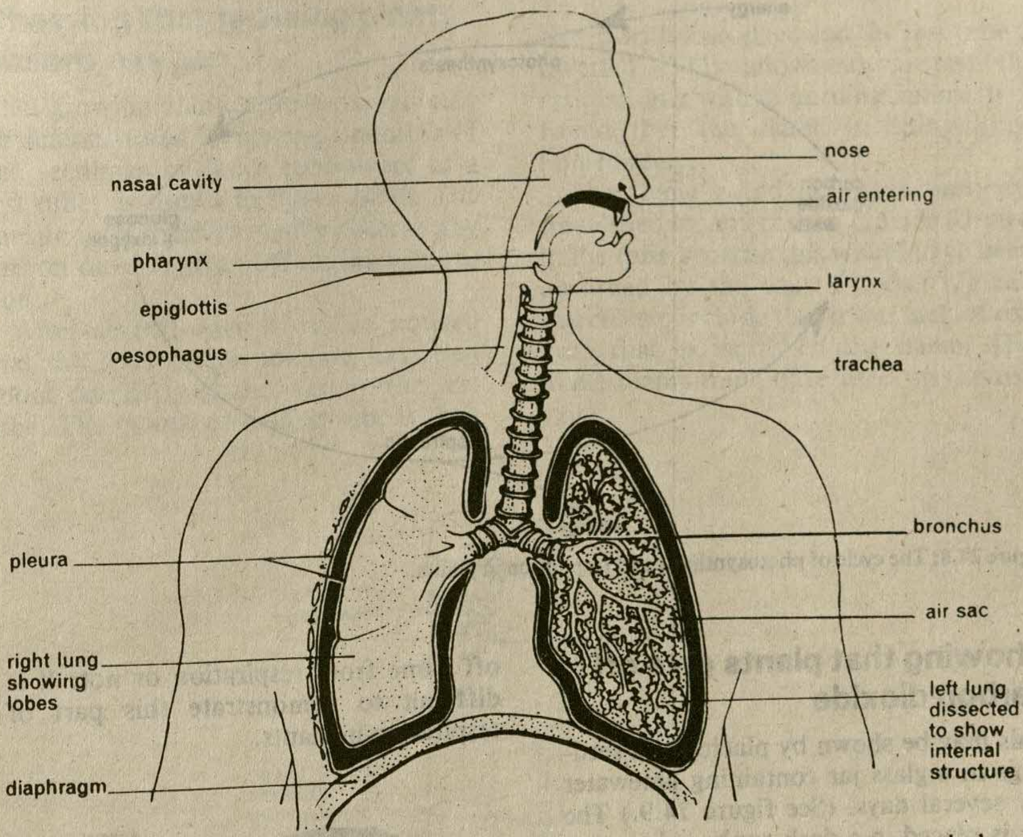


Figure 24.7: The lungs and associated parts. The diagram shows how the diaphragm compresses the lungs during expiration.

Respiration in plants

Plants manufacture their own glucose by photosynthesis. Some of this glucose is used immediately; the remainder is changed to starch and stored for future use. As the plant needs food for its cells the starch is changed back to glucose.

Plant respiration is much the same as animal respiration. Glucose combines with oxygen to liberate energy and give off carbon dioxide and water.

$$\text{glucose} + \text{oxygen} \rightarrow \begin{matrix}\text{carbon}\\\text{dioxide}\end{matrix} + \text{water} + \text{energy}$$

The energy is used by the plant to do all the work connected with living and growing.

Respiration and photosynthesis form a cycle. Respiration releases the energy that has been locked up in glucose by photosynthesis. The energy to keep the cycle moving comes from the sun. (See figure 24.8, on the next page.)

Photosynthesis and respiration take place in a plant at the same time, provided the plant is in sunlight. Photosynthesis takes in carbon dioxide and water while respiration gives out carbon dioxide and water. It is therefore more difficult to demonstrate respiration in plants than it is in animals.

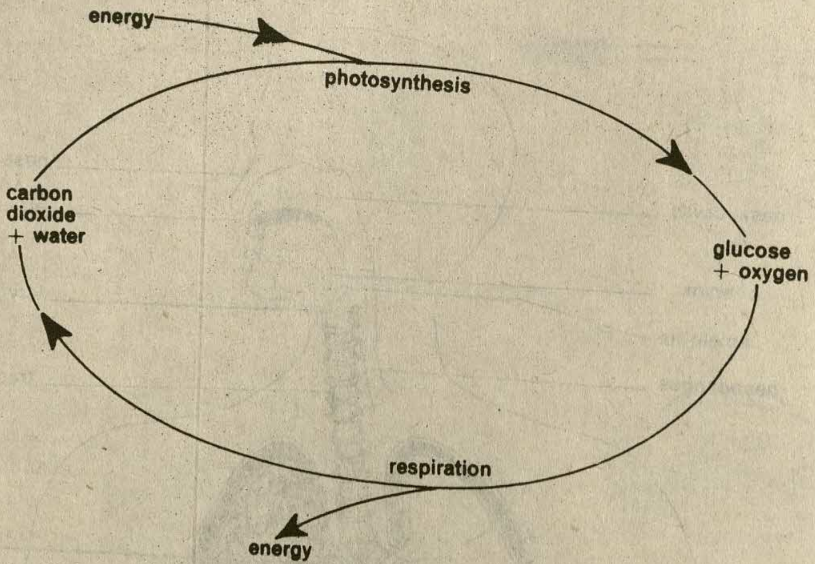


Figure 24.8: The cycle of photosynthesis and respiration in plants.

Showing that plants give off carbon dioxide

This may be shown by placing pea seedlings in a glass jar containing limewater for several days. (See figure 24.9.) The jar is placed in a dark cupboard to stop photosynthesis and a second jar containing limewater but no seeds is placed alongside as a control.

After two days the limewater in the jar containing the seedlings is quite cloudy, while the limewater in the control jar is unchanged. This indicates that carbon dioxide has been given off by the seedlings.

Showing that plants give off water vapour

This was shown in chapter 23 when dealing with transpiration. (See figure 23.4, page 248.) The experiment gave no indication whether the water vapour given off came from respiration or not. It is difficult to demonstrate this part of respiration in plants.

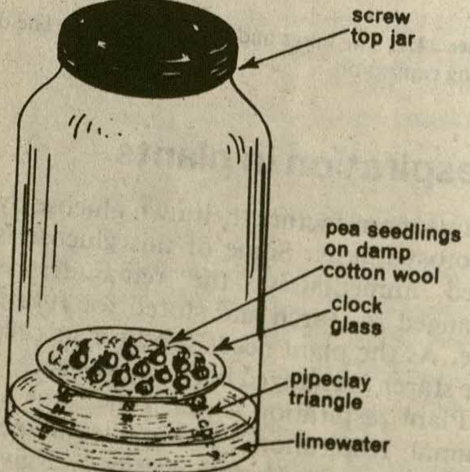


Figure 24.9: An experiment to show respiration in pea seedlings. When the jar is placed in the dark, the limewater becomes cloudy because of the carbon dioxide given off. The limewater in a second jar without seedlings does not change.

Showing that growing plants absorb oxygen

That growing plants absorb oxygen may be demonstrated by placing a number of pea seedlings in damp cottonwool in a test tube, as shown in figure 24.10. The caustic soda solution readily absorbs any carbon dioxide given off during respiration.

After several days it will be noticed that the level of the solution has risen about one-fifth of the way up the test tube. The mouth of the test tube is then closed with a stopper and the test tube is inverted. This allows us to test the residual gas with a burning splint. It is found that the flame is extinguished immediately.

The flame could not have been extinguished by any carbon dioxide formed in the tube because this would have been absorbed by the caustic soda. We can therefore conclude that it was lack of oxygen that extinguished the flame. The living plants must have used up the oxygen.

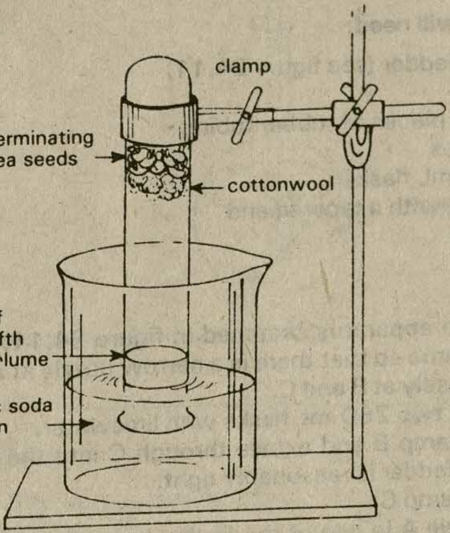


Figure 24.10: Apparatus to show that growing plants absorb oxygen. The test tube is standing in a beaker of caustic soda solution, which absorbs any carbon dioxide produced during respiration.

EXPERIMENT

24.1

Is heat given out by plants during respiration?

Each group will need:

- two vacuum flasks
- two 100°C thermometers
- ten packets of pea seeds
- cottonwool
- beaker
- tripod
- gauze
- Bunsen burner

What to do

- Mix the seeds from the different packets and soak them in water for 24 hours.

- Divide the seeds into two equal heaps and boil one heap in water for ten minutes to kill them. Allow them to cool.
- Place the heap of live seeds in one vacuum flask and the other heap in the other flask.
- Fit a thermometer in each flask so that the bulb is in the middle of the seeds.
- Pack cottonwool into the top of each flask.
- Record the temperature of each heap of seeds once a day for a week.

Questions

24.1 Was there any difference between the temperature recordings of the two flasks? If there was, what did it indicate?
24.3 What was the purpose of having one flask containing killed seeds?

EXPERIMENT 24.2

Does the composition of your breath change after hard exercise?

Each group will need:

- football bladder (see figure 24.11)
- T-piece
- two short pieces of rubber tubing
- two clamps
- two 250 mL flasks
- glass tube with a tapered end
- limewater

What to do

- Set up the apparatus sketched in figure 24.11. The glass tube is drawn out in a flame so that there is a narrow nozzle at A. Two screw clamps are placed loosely at B and C.
- Almost fill two 250 mL flasks with limewater.
- Tighten clamp B and exhale through C into the football bladder. Do this until the bladder is reasonably tight.
- Tighten clamp C.
- Place nozzle A in one of the flasks, loosen clamp B and allow the exhaled air in the bladder to empty through A. Squeeze the bladder to empty it.
- Run around the yard until you are panting from exercise.
- Again breathe into the bladder through C and repeat the procedure using the second flask of limewater. See that the bladder is inflated to the same pressure each time and that the exhaled air comes through the nozzle at the same rate into each lot of limewater.
- Shake both flasks and compare the precipitates.

Questions

24.3 Which flask contained the greater amount of precipitate?
24.4 In which case had there been a greater amount of respiration?
24.5 Why was there a difference between these two rates of respiration?
24.6 Where did the extra energy needed for running come from?

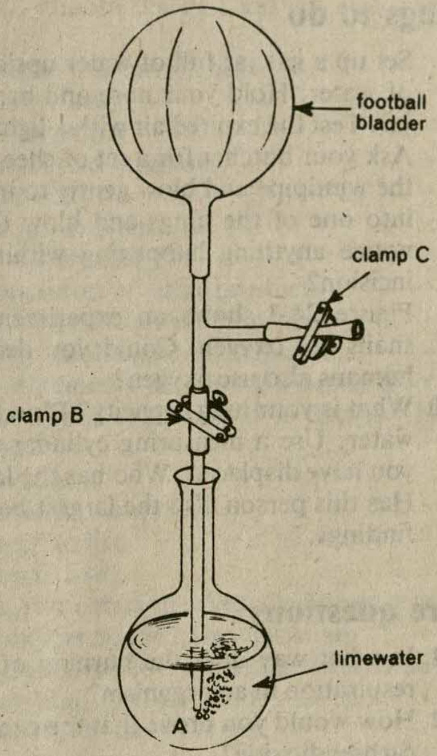


Figure 24.11: Apparatus used in experiment 24.2.

Respiration

1. Respiration takes place in cells.
2. In respiration:
   - glucose combines with oxygen
   - energy is liberated
   - carbon dioxide and water are excreted.
3. Respiration increases when energy is used more rapidly.

Spelling list

bronchi
capillary
carburettor
cycle
diaphragm
larynx
precipitate
respiration
trachea

Things to do

24.7 Set up a gas jar full of water upside down on a shelf in a large dish of water. Hold your nose and breathe out through a tube into the jar. Test the expired air with a lighted taper.

24.8 Ask your butcher for a set of sheep's lungs. Push a glass tube down the windpipe and blow gently to inflate the lungs. Make an incision into one of the lungs and blow through the tube again. Can you notice anything happening within the lung where you made the incision?

24.9 Figure 24.3 shows an experiment designed to demonstrate that snails use oxygen. Could you design an experiment to show that humans also use oxygen?

24.10 What is your lung capacity? Blow into a large inverted bottle full of water. Use a measuring cylinder to measure the volume of water you have displaced. Who has the largest lung capacity in your class? Has this person also the largest body? Account for any unexpected findings.

More questions

24.11 In what way does the burning of petrol in an engine differ from respiration in an organism?

24.12 How would you prove that the exhaust gases of a motor car contain carbon dioxide?

24.13 Why do you breathe faster than normal during heavy exercise?

24.14 After running and jumping you feel hot. Why?

24.15 What kind of disease is a respiratory disease?

24.16 What is artificial respiration? How is it applied?

24.17 How is oxygen for respiration obtained by fish, ants, worms, tadpoles and frogs?

24.18 Find out what you can about the rate of respiration of hibernating animals. Does the body temperature of a hibernating bear drop? Does its rate of breathing decrease?

24.19 Why does the death of an organism take place within a few minutes of its being deprived of air, yet takes much longer if the organism is deprived of food?

24.20 What do you think we would find if we compared our rates of respiration on a hot day and on a very cold morning? Could there be a difference? Why?

Test yourself (chapter 24)

Write the answers to questions 1 and 2 in your workbook.

1. Name one process that takes place in all living plant and animal cells.
2. During respiration a cell has to rid itself of two waste products. What are they?

In questions 3 to 7, choose the best answer and write its letter in your workbook.

3. Respiration in humans is carried out in:
   (a) cells of the lungs only
   (b) cells of the blood only
   (c) cells of the nose and lungs only
   (d) all cells of the body.
4. The main action in respiration is:
   (a) drawing air into the lungs
   (b) ridding an organism of waste products
   (c) building up food substances in the body
   (d) making energy available to the organism.
5. Below are four statements describing a newly discovered living thing. Which statement could best be used to decide whether the thing is a plant or an animal?
   (a) It is able to respire.
   (b) It is able to make its own food.
   (c) It needs oxygen to live.
   (d) It needs water to live.
6. During breathing, air enters the chest cavity because:
   (a) some of the oxygen in the lungs is used up
   (b) the diaphragm moves down, making the internal pressure less
   (c) the expanding lungs pull air into the air sacs
   (d) air flows in to fill the empty lungs.
7. One of the substances used in respiration is glucose. The other substance is:
   (a) water
   (b) air
   (c) oxygen
   (d) blood.

25

The balance of life

Life on the earth exists in a very narrow zone called the *biosphere*. This zone has been teeming with life for hundreds of millions of years. A large number of organisms have lived, died and decayed during this long period. These have used vast quantities of substances from the air and the soil. Yet the composition of the air and soil apparently has not changed in millions of years. What is the explanation of this? How is this balance between living and non-living things maintained?

The aquarium

An aquarium can give us some understanding of how this balance is maintained.

A sealed aquarium is shown in figure 25.1. The setting up is described in experiment 25.1. The aquarium may be regarded as a small isolated community of plants and animals. The exchange of materials between these plants and animals maintains a balance in the aquarium.

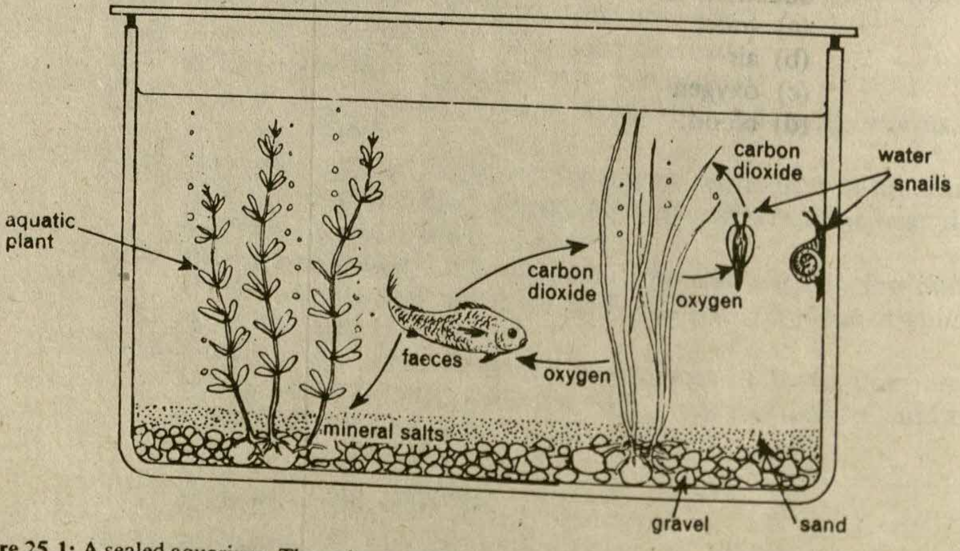


Figure 25.1: A sealed aquarium. The animals are balanced against the plants.

The plants use carbon dioxide, water and light to make glucose. This glucose, together with water and salts from the sand, is used for growth. The animals eat the plants. In this way they obtain the carbohydrates, proteins and salts they need for their growth.

At the same time the animals respire. The carbon dioxide given off as a result of respiration is absorbed by the plants to make more glucose. During the making of this glucose, oxygen is liberated and is used by the animals in further respiration.

Salts are required continuously by the plants for growth. A supply of these salts is maintained by the action of bacteria. These bacteria live on the bodies of dead organisms and the faeces from living animals. They cause the decay of this refuse, and the decay produces the salts.

What keeps all this going and so keeps the balance between living and non-living things maintained? It is the light that shines on the leaves of the plants. This light helps to manufacture the glucose that is the source of energy for the aquarium.

In a balanced community such as this aquarium, as much energy must be given out as is absorbed. How does this energy come out of the community? It is given out as heat during respiration of the organisms and during the decay of dead material.

Open woodland

Keeping in mind what we have learned about an aquarium, we shall now look at an area of open woodland not used by people to see whether the same cycles operate and whether there is a balance between them.

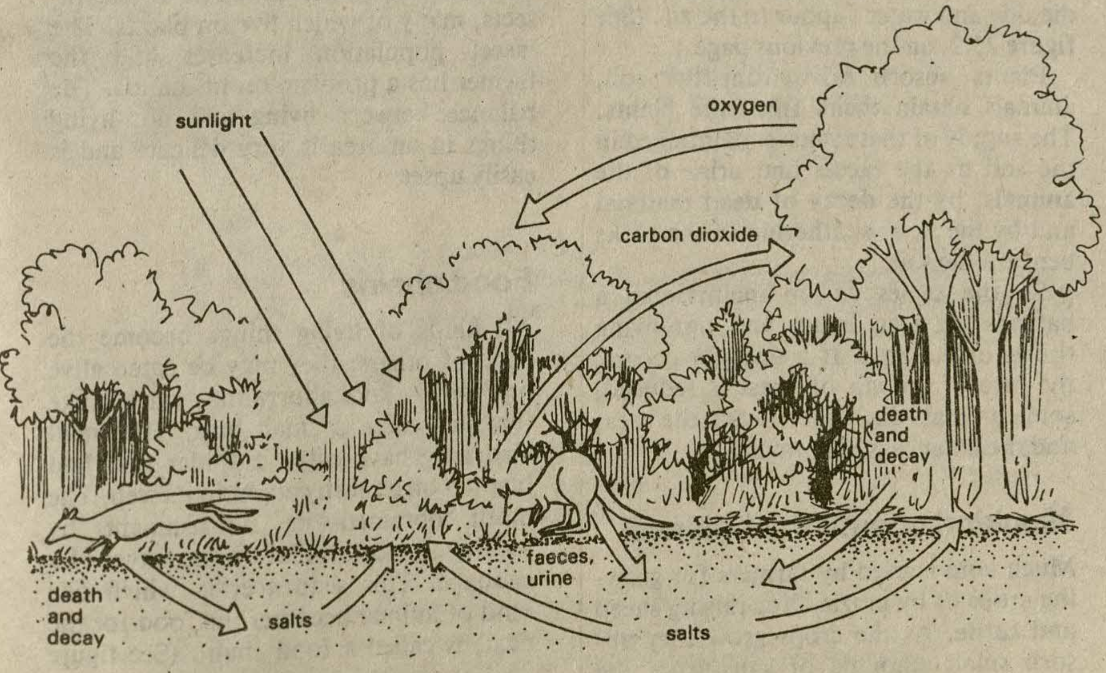


Figure 25.2: Some of the cycles in an area of open woodland.

By open woodland we mean an area of country containing some tall trees with open stretches of grassland in between. There would be layers of rotting leaves, bark and twigs beneath the trees and droppings from the larger animals over the whole area. Many different kinds of animals would be living in the area. There would be millions of minute bacteria in the soil, a variety of insects and birds, possums, kangaroos, echidnas, and perhaps wombats and phascogales (brush-tailed marsupial mice).

The energy for the plants comes from the sun. Some animals, such as the wombats and the kangaroos, obtain their energy by eating plants; others, such as spiders, snakes, echidnas and phascogales, by eating other animals.

Plants use the sun's energy to produce glucose from carbon dioxide and water vapour. Both animals and plants use this glucose in respiration and return carbon dioxide and water vapour to the air. (See figure 25.2, on the previous page.)

Plants absorb salts from the soil, animals obtain theirs from the plants. The supply of these salts is maintained in the soil by the faeces and urine of the animals, by the decay of dead material and by the slow weathering of the rocks beneath the soil.

So the cycles go on maintaining a balance between living and non-living things in the area. If a drought occurs, the rate of growth of grass is reduced, some animals die, others leave the area, and the balance is maintained.

Mankind upsets the balance

Much land is used by farmers for growing crops or by graziers for raising sheep and cattle. As the crops grow they absorb small amounts of salts from the soil. The sheep and cattle eat grass, which also takes salts from the soil. A balance would be maintained if the crops and the animals were allowed to die and rot in the area, but the crops and animals are harvested and taken away. Slowly the supply of essential salts is depleted. They are taken out of the soil faster than they can be replaced from the rocks beneath. The farmer must therefore use fertilizer to make up the deficiency. This has to be done carefully, because there are many trace elements in the soil that may not be part of the fertilizer that is added.

The farmer has upset the balance in another way as well. He has probably removed a number of native trees and shrubs. These took nourishment from the soil that has now become available to crops and grass. But the trees and shrubs were the habitat of birds and other animals. They leave the area and are therefore no longer available to eat insects, many of which live on plants. The insect population increases and the farmer has a problem on his hands. The balance between living and non-living things in an area is very delicate and is easily upset.

Food chains

All kinds of living things become the food of others; they may be eaten alive or dead. A kookaburra may eat a snake that has eaten a small bird. The small bird may have eaten a spider that had just fed on a moth caught in its web. The moth obtained its nourishment by feeding as a caterpillar on the leaves of a cabbage. This sequence, in which one kind of animal becomes the food for the next, is called a food chain. (See figure 25.3.)

All food chains begin with green plants. The plants need not be alive; their leaves and twigs may be decaying on top of the soil and providing food for such animals as worms. Figure 25.4 shows two more food chains; both of these, as with all others, commence with green plants.

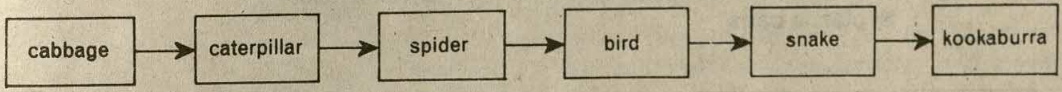


Figure 25.3: A food chain. The animals at the end of the chain are bigger but those at the beginning of the chain are more numerous.

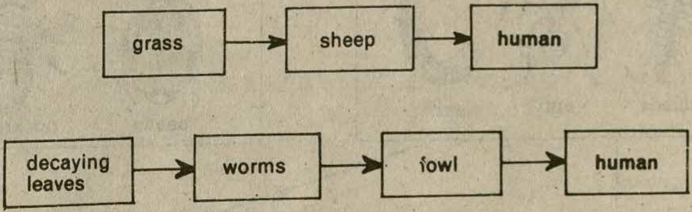


Figure 25.4: More examples of food chains.

EXPERIMENT 25.1 *Setting up an aquarium*

Each group will need:

- fish tank
- gravel
- sand
- stones
- aquatic plants
- freshwater snails
- fish

What to do

- Thoroughly clean the glass tank.
- Wash some freshwater gravel and sand; place about two centimetres of gravel on the bottom of the tank and cover it with the same depth of sand.
- Place the aquarium in a position that is well lit by indirect sunlight.
- Fill it with water, preferably from a pond rather than a tap.
- Add some aquatic plants and one or two stones.
- Allow to stand for a week.
- Put in some fish and some freshwater snails. The rule, one centimetre of fish per two litres of water, gives you an idea of how many fish to put in.
- Cover the tank with a sheet of glass.

Questions

25.1 Why must the aquarium be placed in the light?
25.2 Why use sand and gravel instead of soil?
25.3 What happens if you have too many animals in the tank?
25.4 Pond water is preferable to tap water. Why?

EXPERIMENT

25.2

What can you find under leaf litter?

Each group will need:

- pair of tweezers
- small brush
- small wide-necked bottles
- plastic bags
- rubber bands
- thermometer
- hand lens

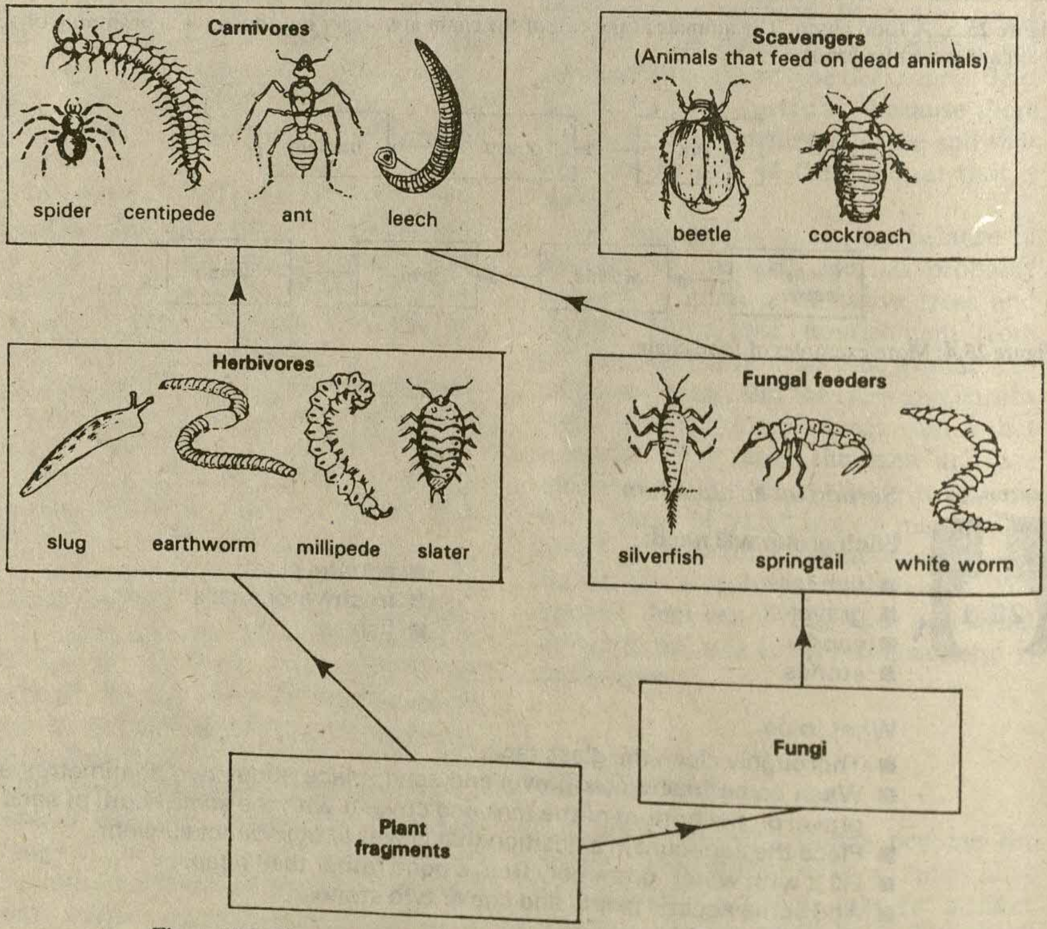


Figure 25.5: Some animals found in leaf litter.

What to do

- Select an area of leaf litter, either in the bush or in the garden, that has been undisturbed for some time.
- In one part of your area of leaf litter, compare the size of the pieces of leaves and twigs at the top of the litter with the size of those at the bottom.
- Compare the amount of moisture top and bottom.

- Compare the shade temperature at the top of the litter with the temperature at the bottom.
- Now, in an undisturbed area of leaf litter, carefully remove some of the top leaves.
- Examine various layers of the litter, keeping a sharp look-out for animals. One way of separating the animals from the litter is to mix it with water and allow the animals to float to the surface. Figure 25.5 shows some of the animals that are likely to be found.
- Bottle one specimen of each kind of animal seen in the litter. Use your tweezers to move such animals as spiders and centipedes, and a wet brush for very small animals.
- Try to identify each animal you have collected and find out what its food is.

Questions

25.5 What is detritus?

25.6 Where did you find the most decomposition in the leaf litter — on the surface, in the middle or at the bottom? Why?

25.7 Is there any difference in temperature between the top and bottom? Can you explain your answer?

The balance of life

1. In undisturbed areas there is a balance between living and non-living things.
2. Non-living substances may be used over and over again in the bodies of different living things.
3. The sun is the source of energy for living things in any natural community.
4. The natural balance of an area may be upset when people use it.

Spelling list

aquarium
centipede
community
detritus
faeces
kookaburra
millipede
phascogale

Things to do

25.8 Make a compost heap in a 20 litre tin. Punch several holes in each side of the tin, about 2 cm from the bottom. Place about 10 cm of grass clippings and chopped-up leaves and twigs in the tin and cover with 2 cm of damp soil. Add more plant material and garden soil in alternate layers until the total depth is about 30 cm. At weekly intervals take the temperature at the top and in the centre. Open up the heap a little and look for threads of fungus. Look also for changes in the appearance of the plant material, and note any animals found in the heap.

25.9 On a bush-walk or a trip to a national park, look for disturbance to the bushland community. Note whether any exotic plants have intruded. Note also any evidence of disturbance by people passing through or picnicking.

More questions

25.10 Imagine you have a balanced aquarium in the school laboratory. Explain what might happen if it were placed in very dim light.

25.11 Explain how it is that a layer of leaf litter in the bush remains much the same thickness despite the fact that new leaves are falling all the time.

25.12 Why do some people pump air through their aquaria?

25.13 Make up food chains ending with (a) a kangaroo, (b) an eagle, (c) a tiger.

25.14 Make a list of the foods you had for breakfast. Consider where each came from and how it obtained its energy for growth.

25.15 What would you do to show that garden soil contains soluble salts?

25.16 Why is rotting plant material necessary in soil?

25.17 What do silverfish live on in (a) the home, (b) leaf mould?

25.18 Spiders trap insects in their webs but do not seem to eat them as we eat our food. How does a spider obtain its nourishment from its prey?

Test yourself (chapter 25)

Write the answers to questions 1 and 2 in your workbook.

1. The diagram below represents a complete food chain. "X" represents the first organism in it — what type of organism must it be?

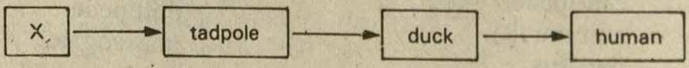
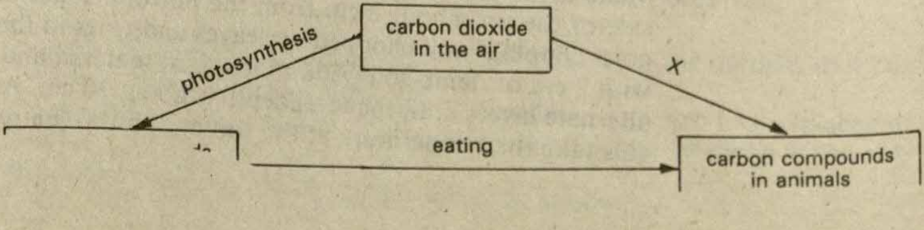


Figure 25.6

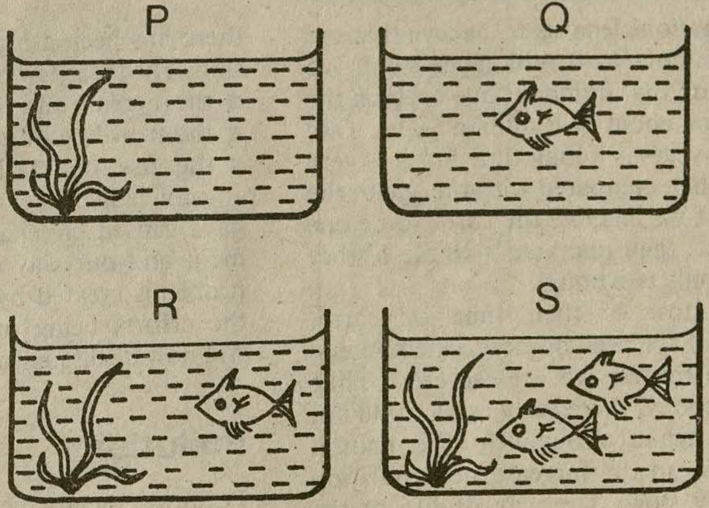
2. The diagram below shows part of a chemical cycle important in nature.



Name the process labelled "X".

In questions 3 and 4, choose the best answer and write its letter in your workbook.

3. In the food chain
   X⟶Y⟶Z
   X is eaten by Y, which is eaten by Z.
   In all cases X must be:
   (a) a small animal
   (b) a large animal
   (c) a plant
   (d) a fungus.
4. Some fish tanks were set up in a light airy place, as shown in the diagram.



After a few days the water in each tank was tested for oxygen. The water that contained the most oxygen was in the tank labelled:

(a) P
(b) Q
(c) R
(d) S.

26

The environment and us: some problems

Investigations lead us to believe that the earth is about 4000 million years old. We also think that humans have been on the earth for about one million years. One million years is a long time but it is very short when compared with the age of the earth. If we imagine the earth to be one year old, then mankind's whole history covers only two hours.

For most of their time on earth, humans have been hunters. The hunters' struggle for survival was severe. Unlike people today, these early races could not provide against drought or other natural disasters, so the increase in population was very slow. The way of life of the Australian Aborigine gives us some idea of the life style of the early peoples.

Then came a change. Slowly mankind learned to farm the soil. This made life more secure. People were able to grow crops, store food and live in permanent villages. Remnants of early villages found by archaeologists in the Middle East show that village life was established there about ten thousand years ago.

The third stage in human development was the use of machines. This resulted in the growth of large cities with many factories. This growth has occurred in the last two hundred years. During this time there has been a big increase in population. The three factors,

- the increase and spread of population
- the crowding of people in huge cities
- the use of machines and scientific knowledge,

have caused big changes in the environment and our way of life. Some of the problems created by these changes, and the efforts being made to solve them, will now be discussed.

Pollution

Pollution means the spreading of harmful or unpleasant substances. Pollution may occur in the air, the soil, the rivers or the ocean. It may take the form of smog hanging over a city on a winter's morning or it may be caused by the use of a pesticide on a farm. It may be merely unpleasant or it may destroy all life in the polluted environment.

Pollution in cities

Most cities have grown without serious planning either for efficiency or for the welfare of the people who live in them. Cities have many problems. One of these is the disposal of waste. This waste includes:

- smoke from factories, power stations and oil refineries
- fumes from motor vehicles
- liquid waste from factories
- garbage from factories and homes
- sewage.

Smoke. Factory smoke is unhealthy, unsightly and dirty. This kind of pollution is worst in winter because the smoke-laden air is cold and remains close to the ground. (See figure 26.1.) Its effect can be reduced by building factories where prevailing winds carry the smoke away from the city.

In Sydney the prevailing winter winds are westerly, blowing over the city out to sea. Therefore the factories giving off smoke should be built on the coast. Even in summer the coast is the best position for these factories. The prevailing sea breezes rise when they are heated by the hot land and flow back out over the sea, carrying the smoke with them. (See figure 26.2.)

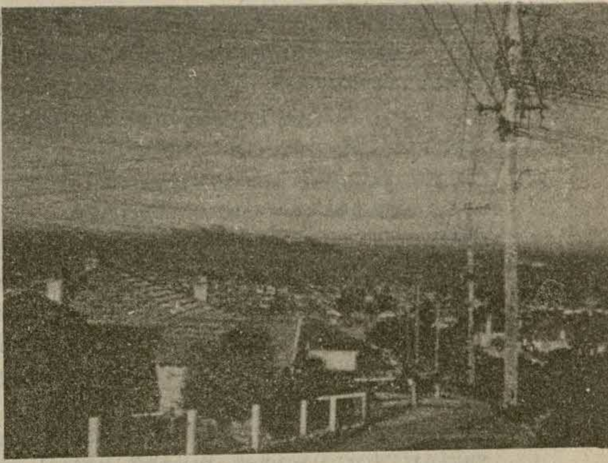


Figure 26.1: Smoke haze over suburbs of Sydney on a winter's morning. The wind is blowing from the right. (Photo courtesy R. P. Murphy, Department of Public Health)

A bad area for building smoke-producing factories would be between Sydney and the Blue Mountains. Winter days are calmer here and the smoke

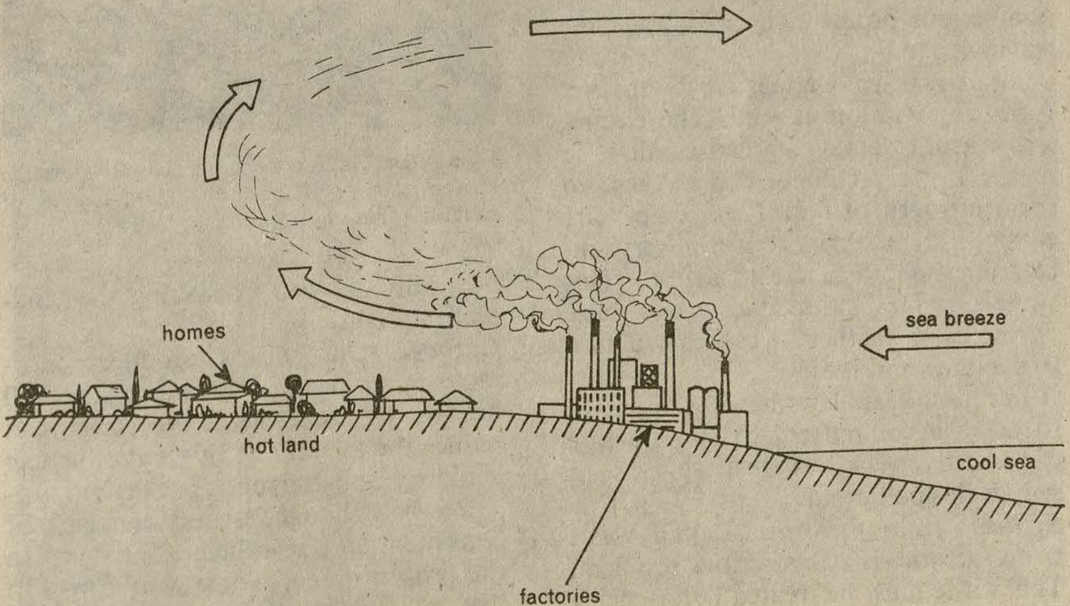


Figure 26.2: The prevailing sea breeze tends to rise over the hot land and carry the smoke back over the water.

would therefore hang for longer periods. The westerlies are the most common winter wind; when these blow, the smoke would be carried over Sydney before it reached the sea. In summer, the sea breezes do not reach as far inland as this.

As well as using the wind to help solve the problem of factory smoke, we can build the factories in such a way that less smoke is produced. Furnaces and chimneys can be designed to absorb most of the smoke before it escapes into the atmosphere.

Motor vehicles. In an earlier chapter we said motor vehicles burned petrol to form the same products as respiration — carbon dioxide and water. However, this is not the complete story. Petrol engines are not very efficient and one of the results of this inefficiency is the formation of some carbon monoxide with the carbon dioxide.

carbon monoxide CO
carbon dioxide CO_2

Carbon monoxide is very poisonous and is a serious problem in cities when the traffic is dense.

Modern petrol engines create another form of pollution as well. The electric spark at the spark plug causes nitrogen in the air to combine with oxygen, to form nitrogen oxides. These oxides are changed by sunlight to form very unpleasant photochemical smog. This smog envelops cities as a brown haze during calm weather. It causes irritation to the lungs and eyes.

In recent years laws have been passed to make it compulsory to manufacture cars with special exhaust systems to reduce this pollution.

Effluent from factories. Liquid waste from factories is also a serious problem. This waste must be treated before being allowed to flow into creeks or rivers, for pollution of this kind can kill fish and other life, as well as making the landscape unsightly.

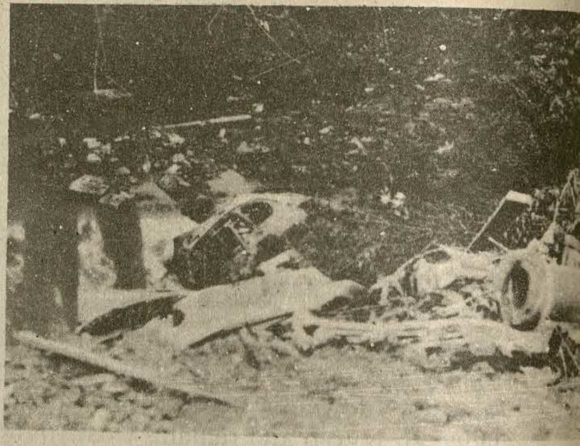


Figure 26.3: The pollution of a creek by garbage and by liquid wastes from a factory. This creek flows into Sydney Harbour.

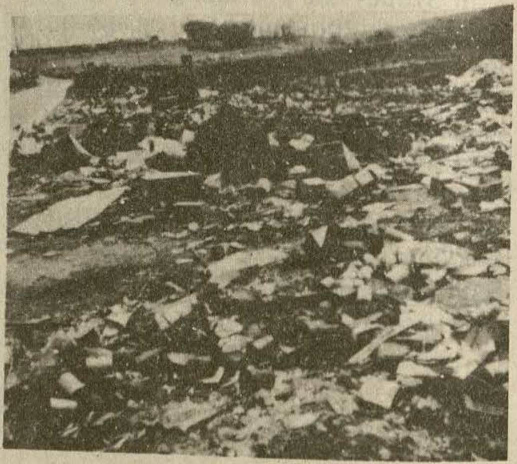


Figure 26.4: This is not a municipal garbage dump but an example of the thoughtless dumping of rubbish by passing motorists.

Garbage. Our society produces enormous quantities of solid waste and it all has to go somewhere. Recycling can reduce the amount of this waste; so can avoiding using too much packaging.

People's thoughtlessness and lack of consideration for others contribute to the problem. Few people would wish to live in an area where the creeks and vacant land were as polluted as shown in figures 26.3 and 26.4.

Sewage. Sewage disposal is another problem. Cities close to the coastline generally empty their sewage into the ocean. Care must be taken to avoid polluting areas used for recreation. Country towns and cities use treatment ponds. These depend on the action of bacteria to break down the sewage into a more disposable form. (See figure 26.5.)

Sewage is a dangerous form of pollution because it almost always carries some of the organisms that cause infectious disease.

Pesticides. Scientists have made many chemicals that may be used by farmers to kill insects that damage crops. These chemicals must be used with care, otherwise the balance of life may be upset and things made worse instead of better.

Such a situation developed in California when an attempt was made to kill scale insects that were destroying orange trees. The chemical used proved to be more effective in killing other insects, such as the ladybird beetle, which were eating the scale. Thus the position became worse than before.

Pesticides kill insects such as bees, which pollinate flowers. This can reduce the yield from crops. The destruction of the insects may also affect bird life, because birds live on insects. With a reduction in the number of birds, the balance could be upset and the numbers of other insect pests increase.

Humans and other animals absorb chemicals from food crops sprayed with pesticides. Many of these chemicals are very poisonous and could have harmful effects on other forms of animal life, including human. There is no knowing how far pollution of this kind may extend. For example, penguins have been found in Antarctica whose bodies contained traces of DDT that must have been used on another continent.

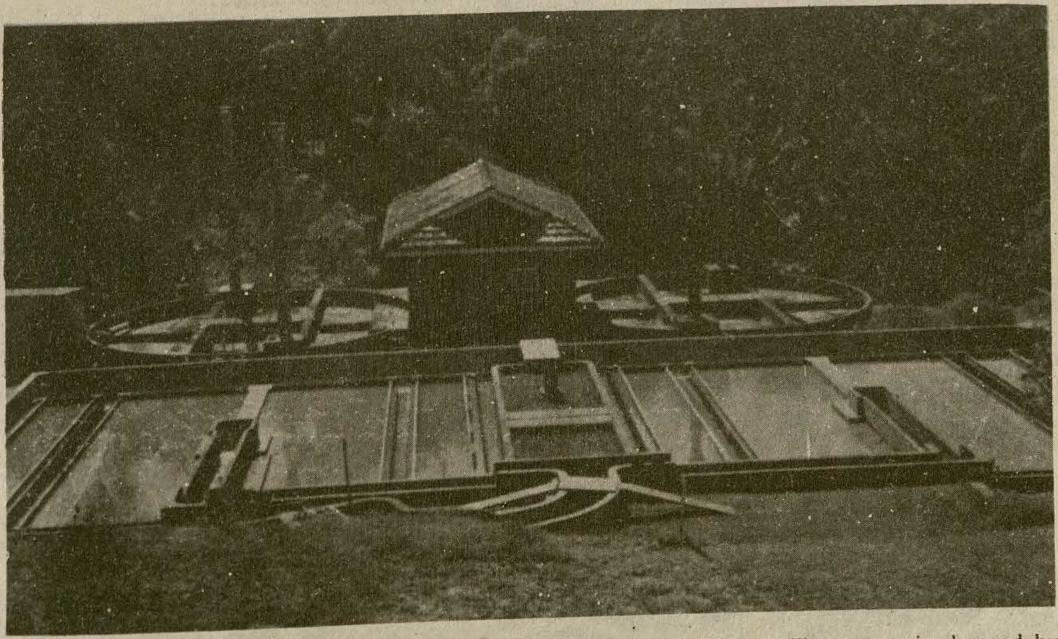


Figure 26.5: Ponds for treating sewage near Hornsby, New South Wales. The sewage is changed by bacteria into a clear solution.

Shortage of resources

Modern society is developing in such a way that we are gobbling up more and more of the world's natural resources at a faster and faster rate.

The biggest problem is *energy* — energy for factories, transport, homes and communication. We have been told by experts that reserves of petroleum will be exhausted early in the twenty-first century. Coal will last much longer but it too must eventually be exhausted. Some of the problems facing scientists and engineers at present are:

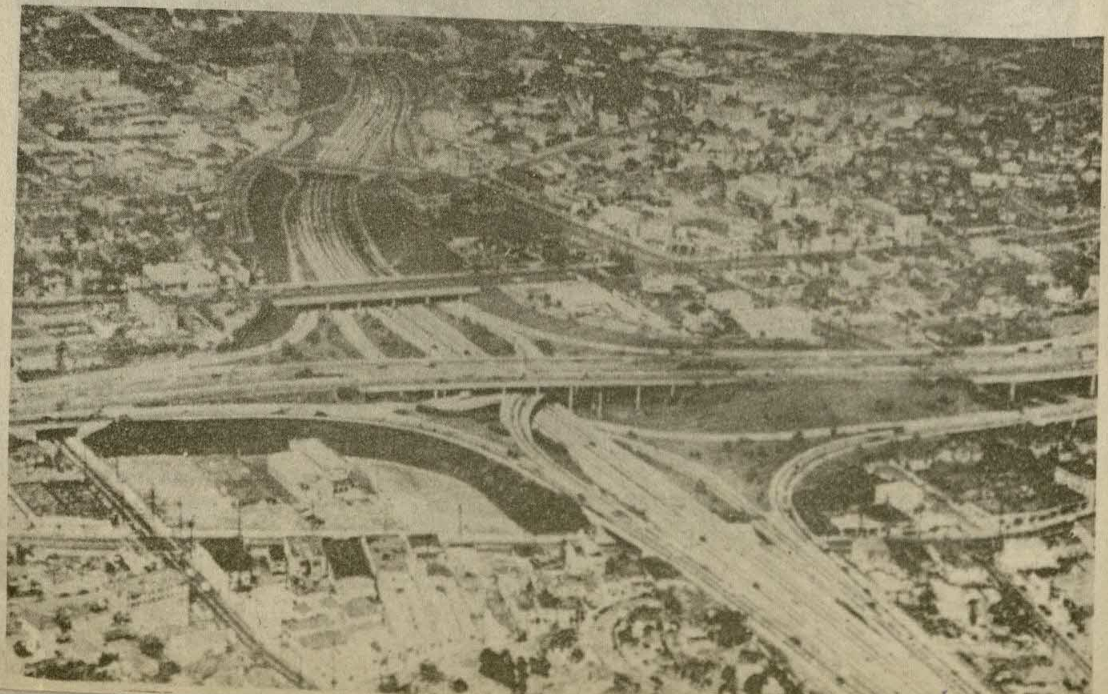
- how to convert coal to petrol cheaply
- how to build nuclear power stations that have no risk of pollution
- how to design an atomic reactor that will change hydrogen into helium (this is the reaction going on in the sun and producing the sun's energy)
- how to trap the sun's energy cheaply.

These are only some of the problems. A more detailed study of the depletion of the world's resources will be presented in a later book.

Problems of big cities

Traffic in cities. With the development of new machinery and techniques, fewer and fewer people are needed to work farms. The result is growth of the cities. It is not the purpose of this book to debate the virtues of city life versus those of country life but we wish to point out at this point that, in some aspects, cities are very inefficient. Think of the very expensive freeways that have to be built so that motorists can get in and out of the city and from one side to the other. No matter how much money is spent on these roads, they are always choked with traffic at peak hours. Three things result from this — waste of time travelling (with resultant frustration), waste of petrol and the pollution of the atmosphere. This is only one example of the inefficiency of cities.

Figure 26.6: Part of the freeway system of Los Angeles. Notice the large area taken up by the freeway. How many houses would have been demolished to make way for it? (Photo courtesy U.S. Information Service)



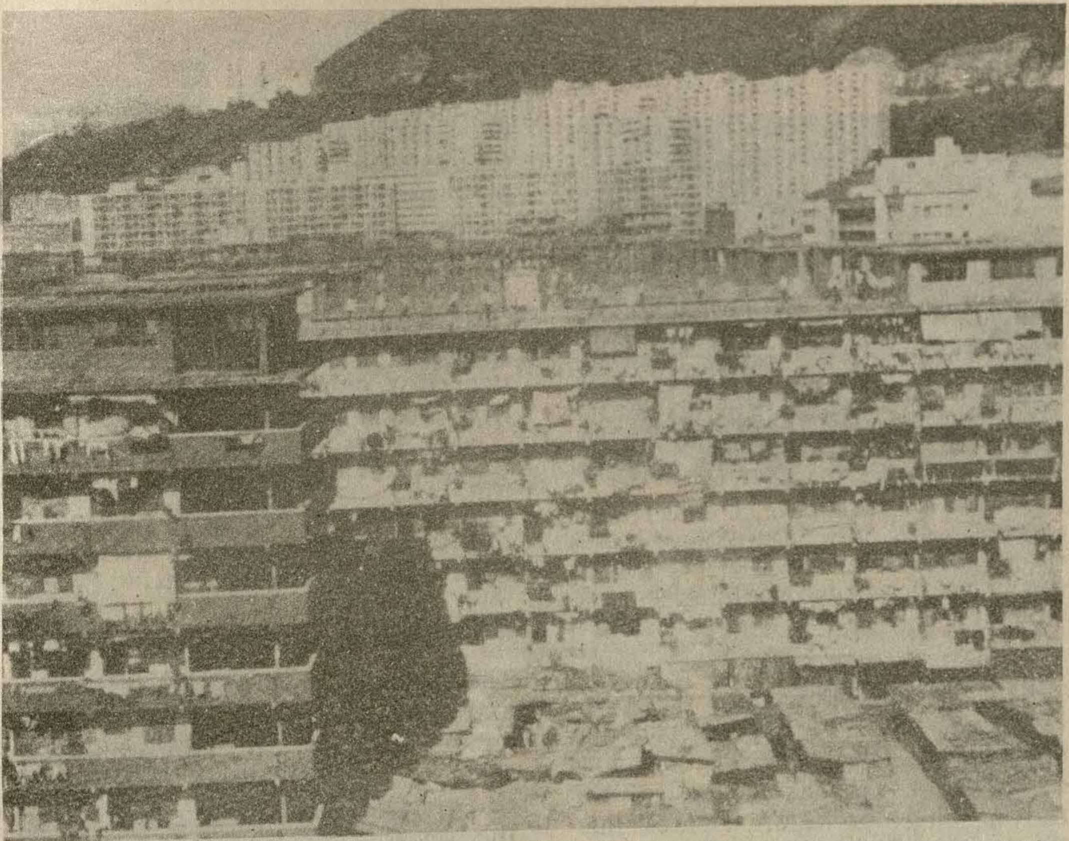


Figure 26.7: City housing — Hong Kong. Notice the hovels in the foreground and the high-rise resettlement flats alongside. Would the tenants of these flats have very much privacy? Would the flats be noisy? What opportunities would these people have for recreation? (Photo courtesy J. Bunyard)

Overcrowding. There is another aspect of city life that is very expensive, not in terms of money but in terms of human happiness and welfare. Many people, especially those on lower incomes, have been forced to live in overcrowded high-rise apartments with little space available for recreation. It is only in recent years that planners have become aware of the need to house people in more open situations where there is more opportunity for recreation. This will help to overcome the bad effects of crowding (see figure 26.7) and to develop a more pleasant community life.

Loss of top soil

Before the coming of Europeans to Australia, the continent was in balance with nature. Although the Aborigines were hunters, they moved around and did not kill too many animals; they did not plough fields to grow crops or herd animals in paddocks to graze.

The white settlers did both these things. They cut down trees, ploughed the land and opened up vast areas for grazing. Unfortunately, the European settlers were completely ignorant of Australian conditions. They cut down far too many trees, allowed fields to stand without crops for too long and put too many animals on the land to graze. These animals ate out the vegetation. With little to hold the soil, much of it was blown away by the wind or washed away by the rain. Figure 26.8 (next page) shows how much soil may be removed in this way.

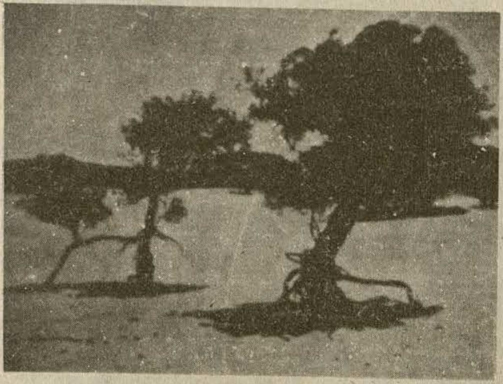


Figure 26.8: Grim evidence of the effect of wind erosion in western New South Wales. About a metre of soil must have been blown away to expose the roots of these trees as much as this.

Badly eroded land recovers very slowly because it takes hundreds of years for soil to form from rocks. People now realize this and are taking steps to hold the top soil and to restore the areas that have already lost it. The following is a list of the ways in which this can be done:

- replanting trees and grasses
- reducing the number of grazing animals, particularly in drier areas
- contour ploughing
- scientific rotation of crops so that paddocks are not left bare for long periods
- filling in gullies caused by erosion and planting vegetation to prevent further erosion.

Conservation

Australia has many unique animals. These, as much as anything else, have made this country known all over the world. For example, when the first specimen of the platypus was preserved and sent to Europe some people refused to believe such an animal existed. It was even suggested that the body had been put together from pieces of other animals: it had a bill and yet it had fur; it laid eggs like a reptile yet it suckled its young. Yet this fabulous animal came close to extinction because it was hunted ruthlessly for its fur. The authorities stepped in only just in time to save it from becoming extinct.

Almost the same story can be told about the koala. For others of our animals, however, we moved too slowly, and they were wiped out before we realized the need to save them.

The problem of the kangaroo

The kangaroo is one of Australia's best-known marsupials. It appears on the national coat of arms. Unfortunately, some species of kangaroo are very close to extinction. The main problem is that the kangaroo, like the sheep, is a herbivore. Because of this it can become a pest to farmers who are growing wheat or raising sheep.

The kangaroo is also a source of meat. The combination of these two facts has resulted in the indiscriminate slaughter of the animal. The CSIRO is at present carrying out a study of the kangaroo in order to preserve it without allowing its numbers to increase to pest proportions.

National parks

Much of our bushland has been destroyed because of the development that goes with an expanding population. To prevent too much destruction, areas have been set aside as national parks. Here native wild flowers and animals can survive and even increase in numbers. So far only two per cent of our land area has been preserved in this way, but we are slowly increasing the amount.

National parks are also greatly used for recreation by people on outings on weekends and during holidays. As more and more people crowd into our cities, the need for national parks and nature reserves will increase. People will need them as refuges from the noise and pace of city life.

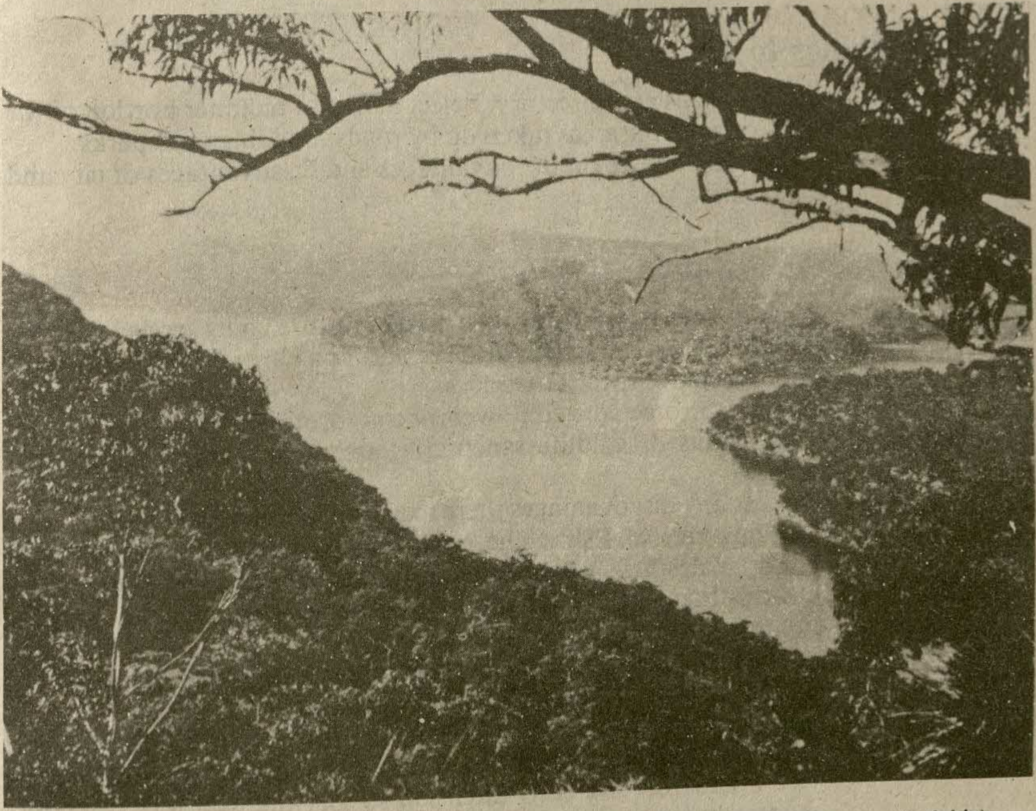


Figure 26.9: A scene in Ku-ring-gai Chase, a national park close to Sydney. (Photo courtesy J. Noble)

The environment and us: some problems

Problems that we need to solve include:

- reduction of pollution
- finding new sources of energy
- overcoming traffic problems
- improving housing conditions
- conservation of soil
- preservation of wildlife
- establishment of nature reserves.

Spelling list

archaeologist
depletion
efficiency
effluent
indiscriminate
pesticide
photochemical
pollution
nuclear
sanctuary
vehicle

Things to do

26.1 Obtain a city street directory. Select a map of an inner portion of the city. Compare the areas taken up by roads, buildings and parks.

26.2 Hold a class debate on the advantages and disadvantages of city and country life.

More questions

26.3 What are some of the methods used to restore badly eroded areas?

26.4 Do you think botanical gardens and zoos are the best places to preserve native species? Discuss.

26.5 Name six protected wild flowers and six protected animals.

26.6 What kinds of wildlife sanctuaries are there other than national parks?

26.7 Discuss any disadvantages there may be in preserving wildlife.

26.8 The numbers of fish in the estuaries and along the coast of New South Wales have become seriously depleted in recent years. How has this happened? Can anything be done to prevent the position becoming worse?

26.9 What problems may be created by the setting aside of areas for national parks and Aboriginal reserves?

26.10 Suppose you were made health inspector for a township that had just been built near a new industrial area. To what particular project would you give early attention so that the health of the community would be preserved?

Test yourself (chapter 26)

Choose the best answer to each of the following questions and write its letter in your workbook.

1. Of the following problems, which is *least* likely to be solved by the methods of science?
   (a) racial prejudice
   (b) food shortage
   (c) air pollution
   (d) heart disease.
2. Many people are worried about the amounts of dangerous or unpleasant pollutants being put into the air. There are some people who

breathe more polluted air than others. Some of these people are:
(a) policemen on traffic duty
(b) coal miners
(c) cigarette smokers
(d) all of these.

3. Select the statement that you think is correct.
   Science has:
   (a) given us better health
   (b) overcome poverty
   (c) stopped the population explosion
   (d) given the answer to all problems.
4. The work of scientists has made a big difference to your life. Which of the following do you think is the *most valuable* effect of science on you?
   (a) better health through vaccines, modern medicines and the scientific study of diseases
   (b) more enjoyable leisure activities, such as water ski-ing, watching colour television and listening to recorded music
   (c) reduction of work because of the invention of labour-saving machines and computers
   (d) easier and cheaper travel, so that today almost anyone can see the world.

Answers to tests

Chapter 3

1. (b)
2. (b)
3. (d)
4. (d)
5. **(a)** 340 mL
   (b) 20 mL
   (c) 160 mL

Chapter 4

1. **(a)** filter funnel
   (b) filter paper
   (c) retort ring
   (d) retort stand
   (e) beaker
   (f) glass rod
   (g) distilling flask
   (h) condenser
   (i) rubber tube
   (j) rubber tube
   (k) clamp
2. (c)
3. (a)
4. (c)
5. (b)
6. (a)

Chapter 5

1. **(a)** margarine, solder, soap, sugar
   (b) water, petrol, icecream
   (c) oxygen
2. **(a)** evaporate, or boil
   (b) condense
   (c) solidify, or freeze
   (d) melt
3. (a)
4. (b)
5. (b)

Chapter 6

1. (c)
2. (c)
3. (b)
4. (b)
5. **(a)** iron sulphide
   (b) potassium nitrate + lead iodide
   (c) copper + iron sulphate
   (d) carbon + water
6. (c)

Chapter 7

1. changes
2. **(a)** potential
   (b) chemical
   (c) kinetic
3. **(a)** chemical
   (b) light
4. heat
5. potential
6. (c)
7. (a)
8. (c)

Chapter 8

1. carbon dioxide
2. nitrogen
3. The composition of air varies from place to place.
4. carbon dioxide
5. magnesium oxide
6. barometer
7. **(a)** thick glass tube
   (b) vacuum
   (c) air pressure
   (d) mercury
8. 76 centimetres of mercury
9. (c)
10. (c)
11. (c)
12. (a)
13. (b)

Chapter 9

1. impure
2. 0°C
3. 0°C
4. (a)
5. (b)
6. (c)

Chapter 10

1. (b)
2. (b)
3. (d)
4. (d)
5. (c)

Chapter 11

1. **(a)** Jupiter
   (b) Mercury
   (c) Pluto
   (d) Jupiter
   (e) Jupiter
   (f) Jupiter and Saturn
   (g) Venus
   (h) Mercury
2. (b)
3. (b)
4. (b)
5. (c)

Chapter 12

1. the water cycle
2. the sun
3. white
4. expands
5. hard
6. aerated
7. (c)
8. (b)
9. (c)
10. (d)

Chapter 13

1. **(a)** solute
   (b) solvent
   (c) solution
2. **(a)** water
   (b) water
   (c) oil or methylated spirits
   (d) methylated spirits
   (e) water
3. **(a)** quickly
   (b) slowly
4. (d)
5. (c)
6. (e)
7. (b)

Chapter 14

1. minerals
2. igneous rocks
3. quartz
4. hornblende
5. **(a)** quartz
   (b) calcite
   (c) feldspar
   (d) hornblende
   (e) mica
6. (a)
7. (d)
8. (c)
9. (b)
10. (c)

Chapter 15

1. calcium carbonate
2. water
3. **(a)** spall
   (b) clay
   (c) clay
   (d) ice
4. (a)
5. (c)
6. (b)

Chapter 16

1. **(a)** moon
   (b) sun or the earth
   (c) earth or the sun
2. **(a)** incident ray
   (b) reflected ray
   (c) angle of incidence
   (d) normal
3. real
4. penumbra
5. smooth
6. (c)
7. (a)
8. (a)

Chapter 17

1. **(a)** assimilation
   (b) stimuli
   (c) reproduce
   (d) grow
   (e) move
2. (b) and (d)
3. (c)

Chapter 18

1. (c)
2. (d)
3. (a)
4. (c)
5. (b)

Chapter 19

1. (b)
2. (d)
3. (c)
4. (d)
5. (d)
6. (c)

Chapter 20

1. A
2. **(a)** nucleus
   (b) membrane
   (c) nucleus
   (d) wall
   (e) vacuole
   (f) cytoplasm
3. (a)
4. (c)
5. (d)

Chapter 21

1. **(a)** meat
   (b) butter
   (c) potato
2. **(a)** liver
   (b) gall bladder
   (c) duodenum
   (d) large intestine
   (e) oesophagus
   (f) stomach
   (g) pancreas
   (h) small intestine
3. (a)
4. (b)
5. (b)
6. (d)
7. (c)
8. (c)

Chapter 22

1. (d)
2. (c)
3. Author prefers (c).

Chapter 23

1. **(a)** chlorophyll
   (b) carbon dioxide
   (c) by transpiration from the soil
   (d) oxygen
   (e) glucose
   (f) in chloroplasts
2. limewater or caustic soda
3. (c)
4. (d)
5. (a)

Chapter 24

1. respiration
2. water and carbon dioxide
3. (d)
4. (d)
5. (b)
6. (b)
7. (c)

Chapter 25

1. plant
2. respiration
3. (c)
4. (a)

Chapter 26

1. (a)
2. (d)
3. (a)
4. Author prefers (a)

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